Government of **Western Australia**
Department of **Water**

Urban Nutrient Decision Outcomes (UNDO) tool

User guide

Version 1.1.0

Water Science Technical Series

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Cover photograph: Perth wetlands (courtesy of Bronwyn Rennie)

Disclaimer

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1 Background

Urban Nutrient Decision Outcomes (UNDO) is a simple conceptual decision support tool with a flexible framework that evaluates nutrient reduction decisions for urban developments on the Swan Coastal Plain in south-west Western Australia. It is specifically designed for ease-of-use by urban development proponents and for assessment by local and state government authorities.

This document provides the user with a step-by-step guide to accessing the model, implementing an urban development, using the various decision options in the tool to reduce nutrients exported from the urban development, and printing and submitting a report to the relevant decision making authority.

1.1 The requirement for a nutrient model

Stormwater runoff is a significant contributor to nutrient export into estuaries, wetlands and lakes on the Swan Coastal Plain. These water bodies are not naturally adapted to high-nutrient conditions and are prone to excessive algal growth as a result of increased nutrient runoff. In many cases, this has resulted in toxic algal blooms, fish deaths, deoxygenation and release of noxious gases and odours, and water bodies unsuitable for boating and recreation. There are major environmental issues (fish deaths, eutrophication, toxic algae), social issues (unsightly water bodies, water bodies not fit for swimming, boating or fishing) and economic issues (millions of dollars per year spent by state and local governments treating these symptoms) associated with elevated nutrients in our receiving water bodies.

It is difficult to prevent the pollution of waterways by stormwater, as the runoff is mostly from diffuse sources. Interdisciplinary catchment-wide approaches are required for successful nutrient reduction. Such approaches involve implementing many best management practices (BMPs) (both structural and non-structural), with the capacity to reduce nutrient export to receiving water bodies. To assess and quantify the effectiveness of various combinations of BMPs in an urban setting, a tool to bring all this information together is required.

Currently, no tool is available to assess the nutrient impacts of development on the Swan Coastal Plain in a consistent and scientifically rigorous manner. The urban development industry and state and local governments have recognised the need to prioritise the development of a tool that can achieve the following capabilities:

- Assess the nutrient impacts of an urban development in a consistent manner supported by local, national and international literature.
- Allow land development proponents to enter data about their development and assess its nutrient impacts in a logical and easy-to-use system.
- Allow land development proponents to make decisions about various management practices that would reduce the nutrient impacts (and adhere to targets if targets are outlined for the development area).

- Report and summarise the design, proposed nutrient management practices and the nutrient exports clearly and concisely.

- Allow assessment by state and local governments to streamline the nutrient-reduction assessment process in a consistent and logical manner.

The development of such a tool will help provide certainty for land development proponents and assessment officers, expediency in nutrient-reduction assessment processes, greater scientific understanding relating to nutrient issues, and efficiencies in investment to manage nutrients.

The UNDO tool brings together some best practice nutrient management options for Western Australia, and can estimate the nutrient export from a development based on a selection of these practices. The tool can be used at the planning stage of urban development so a developer can make planning decisions that will reach target nutrient export rates, or it can be used in an existing urban development to try to quantify the nutrient export reduction after retrofitting the development with various management practices.

The UNDO tool will be used to support nutrient-reduction strategies outlined in local water management strategies and/or urban water management plans prepared under the *Better urban water management* (WAPC 2008) planning framework. This will help develop and deliver local planning scheme amendments, local structure plans and subdivision proposals. The *Better urban water management* framework outlines the requirement of a ‘nutrient management plan’, which involves ‘strategies to minimise the use and application of nutrients on public and private open space’. These plans address nutrient issues associated with urban development and are often required to adhere to nutrient targets. The UNDO tool should be used in conjunction with overarching water sensitive urban design approaches, such as those outlined in the *Stormwater management manual for Western Australia* (DoW 2004–2007) and the *Decision process for stormwater management in WA*: *Draft for consultation* (DoW 2016), to design stormwater management systems that manage stormwater quantity and quality.

1.2 UNDO tool philosophy

The urban development industry and state and local governments have recognised the need for the tool to have the following capabilities:

- Evaluate the nutrient impacts of an urban development in a consistent manner supported by local, national and international literature.

- Allow land development proponents to enter data about their development and to assess its nutrient impacts in a logical and easy-to-use system.

- Allow land development proponents to make decisions about various management practices that would reduce the nutrient impacts of the development (and adhere to the targets established for the development area).

- Report and summarise the development design, the proposed nutrient management practices and the nutrient exports clearly and concisely.
- Allow assessment by state and local governments to streamline the approval process in a consistent and logical manner.

Based on the priorities of the urban development industry, state and local governments, the UNDO tool was designed specifically to adhere to four basic requirements:

1. **Scientific rigour:** The UNDO tool explicitly considers Western Australia's nutrient export processes and pathways. Nutrient input rates, export algorithms and structural BMP efficacy is based on the best available science and local data. The science used to develop the UNDO tool is transparent, concisely documented, and easily accessible from the tool's interface.
2. **Ease of access and use:** All aspects of the design of the UNDO tool have usability as a topmost priority. The tool is web-based, so users can easily access the tool with a web connection. The tool has been constructed using latest software code and development tools, so that it has a modern and intuitive 'feel' to the interface. Users require minimal training, and all help and documentation is easy to access from the main interface.
3. **Ease of review and assessment:** The UNDO tool was developed with assessment by decision-making authorities in mind. Hence, the tool has automatic reporting capabilities, and can save project files. The simple-to-follow format of the reports means that decision-making authority officers can easily understand the BMPs that the proponent will use, and can assess the development's nutrient exports against any guidelines or targets.
4. **Reversion/update capability:** It is recognised that the science surrounding the flux and fate of urban nutrients is constantly evolving, and there is limited local Western Australian data on the efficacy of many of the structural BMPs available in the UNDO tool. So, it is essential that the UNDO tool is developed in such a way that updates are easily implemented when new data becomes available. Version control process and documentation are also provided to streamline the update process.

1.3 What the UNDO tool will not do

It is important for users to understand the limitations of any model. Below is a list of exclusions. The UNDO tool:

- **does not set targets:** While it is recognised that target setting exercises may be crucial in the land-use planning framework, target setting needs to be a process that operates independently of the development of the nutrient decision support tool. If nutrient targets have been set for a catchment, criteria for the UNDO tool can be set whereby the exports calculated by the tool are required to meet target loads.

- **is not a detailed design tool:** The UNDO tool provides first-pass estimates for treatment device sizing *for nutrient treatment*, but the tool does not include hydraulic and rainfall-runoff processes that can be used to accurately design nutrient-reducing structures. It cannot be used to size conveyance, storage or other components of the stormwater management system or to undertake the modelling of any rainfall-runoff processes. The UNDO tool does not include all structural and non-structural BMPs available to treat nutrients or manage runoff quantity. Therefore, the UNDO tool should be used in conjunction with overarching water sensitive urban design approaches, such as those outlined in the *Stormwater management manual for Western Australia* (DoW 2004–2007) and the *Decision process for stormwater management in WA*: *Draft for consultation* (DoW 2016), to design stormwater management systems that manage stormwater quantity and quality.

- **is strictly to assess nutrients:** The tool does not assess other environmental or social factors which may be important to maintain in an urban setting (e.g. biological function, habitat diversity, ecological corridors, urban heat reduction, aesthetics). It does not assess other contaminants that may be relevant in an urban setting (e.g. heavy metals, pesticides/herbicides, hydrocarbons or coliforms). The UNDO tool does not address managing runoff quantity to achieve flood protection, prevent erosion, maintain the hydrologic regimes required for healthy waterways or achieve other quantity management objectives. The tool does not include managing stormwater as a potential water supply source or as part of a total water cycle management system.

- **provides a steady-state solution:** Therefore it does not account for time-dependent processes including:
    - excessive nutrient discharge due to construction (e.g. groundwater de-watering discharge from sewer installation or sedimentation from earthworks and building construction)
    - catchment hydrological changes that occur through time (e.g. reduction in runoff due to tree growth)
    - changes in nutrient export as a result of climate change.

- **does not provide sub-annual solutions:** Daily, seasonal or monthly breakdowns of nutrient exports are not available from the tool.

- **will not always provide accurate answers:** UNDO is a conceptual tool so it is not expected to provide precise answers and some level of error is expected. It is recognised that many subtle variations will affect the export of nutrients (e.g. variations in soil type, soil redox potential, soil biology, vegetation type, surface topography). It is important to find a balance between a tool that is overly simple and lacks adequate precision with a tool that is overly complex and therefore too onerous to use. There is a constant drive in nutrient modelling to push towards a more complex solution but the UNDO tool was designed with usability as a topmost priority, and a simple conceptual model is the most pragmatic tool for the required use in land-use planning.

- **does not consider pre-development nutrients:** The UNDO tool evaluates long-term planning and design for nutrient removal and so does not specifically consider pre-development nutrients (also known as ‘legacy nutrients’) which will generally be flushed from a subsoil system within 2–3 years on the Swan Coastal Plain (Barron et al. 2013). The issue with elevated pre-development nutrients should be considered before applying the UNDO tool, and elevated nutrient concentrations in groundwater may need to be managed concurrently.
- **does not replace existing Department of Water policy and procedure:** Existing Department of Water policies and recommendations regarding best practice water sensitive urban design for urban developments are not compromised by using the UNDO tool in the urban planning process. Using the UNDO tool does not negate any existing procedures.

2 General process for using the UNDO tool

2.1 Where the UNDO tool fits into the planning process

Integrated water planning with land use planning processes for Western Australia is defined in the Western Australian Planning Commissions document *Better urban water management* (WAPC 2008). A flow chart describing each stage of the planning process is shown in Figure 2-1.

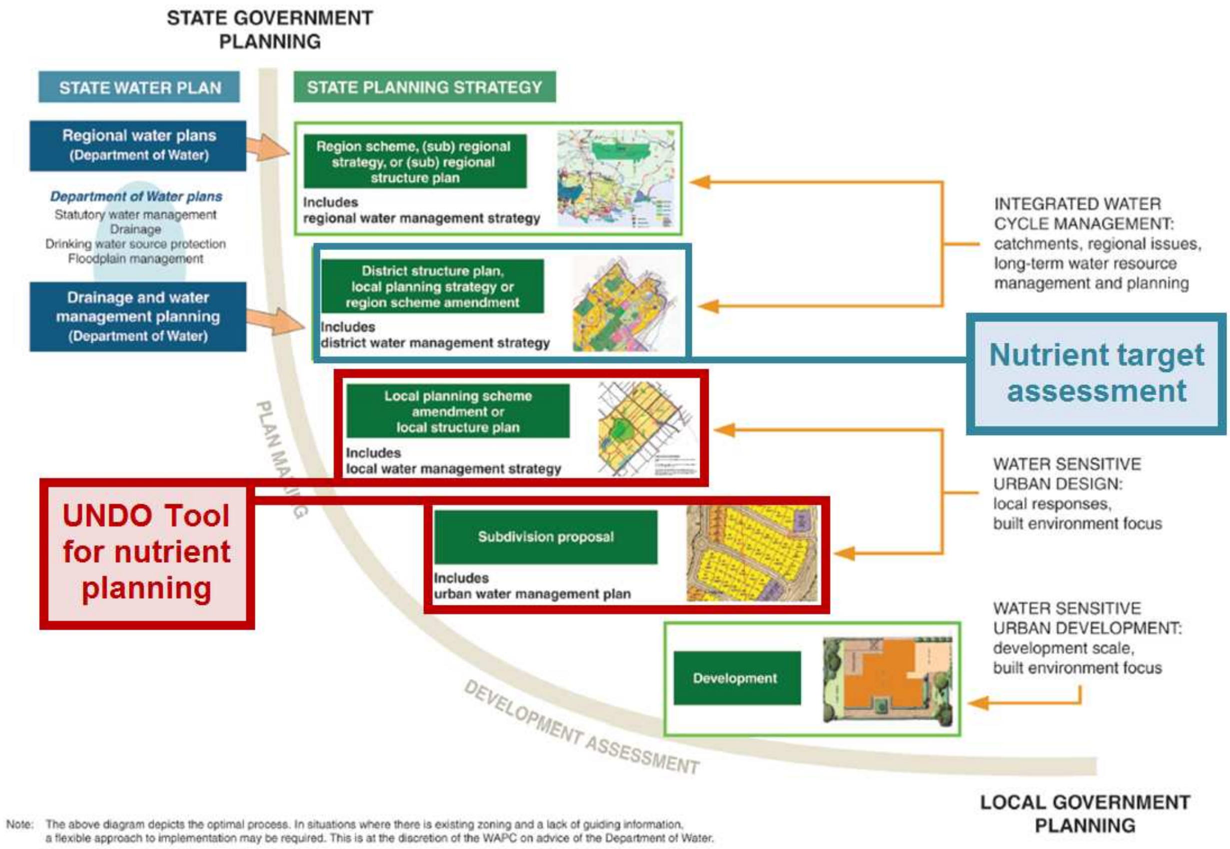


Figure 2-1: *Nutrient planning process within the Better urban water management (WAPC 2008) framework*

Planning and design for appropriate discharge of nutrients from urban developments is primarily done in two stages of the planning process: the district and local stages. This is associated with two water documents: water management strategies at the district and local levels. According to *Better urban water management*, a district water management strategy should:

> *'Define catchment objectives and design objectives for water quality, quantity and conservation for local planning and subdivision'*

At this stage, proponents should explore the nutrient constraints of the development area. This includes finding out if there are existing nutrient export targets or water quality guidelines for the area or its surrounding catchment. The UNDO tool is not generally used at this stage, as many of the design and data requirements for the tool (e.g. lot sizes, landscaping, detailed drainage design) are not yet available. However, by assessing nutrient export guidelines or targets at this stage, developers are provided with a general picture of how constrained the site is by nutrient issues. This provides users with some preliminary planning decisions for when the UNDO tool is applied (for example, if the area is heavily constrained by nutrient issues, the developer will know from the outset that a nutrient-sensitive design is required).

The UNDO tool will generally be used in the local planning stage of the development. According to *Better urban water management*, a local water management strategy contains the following:

- *results of detailed monitoring and modelling of surface water and groundwater quality and quantity*
- *identification of water management infrastructure and strategies required to meet design objectives.*

This is the appropriate level of planning for applying the UNDO tool. The tool's report, generated once the development design is finalised, will generally be submitted as an appendix to a local water management strategy. Local government may also want proponents to use the UNDO tool at the Urban Water Management Plan stage of development.

The UNDO tool may also be used to assess the reduction in nutrients that would result from catchment retrofitting. In these instances, the application of the UNDO tool generally will not be associated with a local water management strategy (depending on the type and scale of redevelopment), and the framework for its use will be project specific.

2.2 Approach to applying the UNDO tool

A flow diagram showing the general approach to applying the UNDO tool for nutrient management in urban developments is shown in Figure 2-2.

The application of the tool should be undertaken in-line with the development's drainage and landscape design as part of the local water management strategy. A pre-requisite for applying the UNDO tool is a map of the development with some preliminary landscape and drainage designs. It is important that these designs are preliminary so adjustments can be made to ensure nutrient targets are met with minimal disturbance to the planning process of the development.

Pre-modelling

Pre-modelling refers to the configuration and calculations required by the user so that data is ready to enter into the UNDO tool. There are two major stages in this: subregion configuration and data configuration. Subregion configuration is where the user decides how many subregions to divide the development into. More information on this is shown in *Appendix A: a guide to configuring subregions in the UNDO tool.*

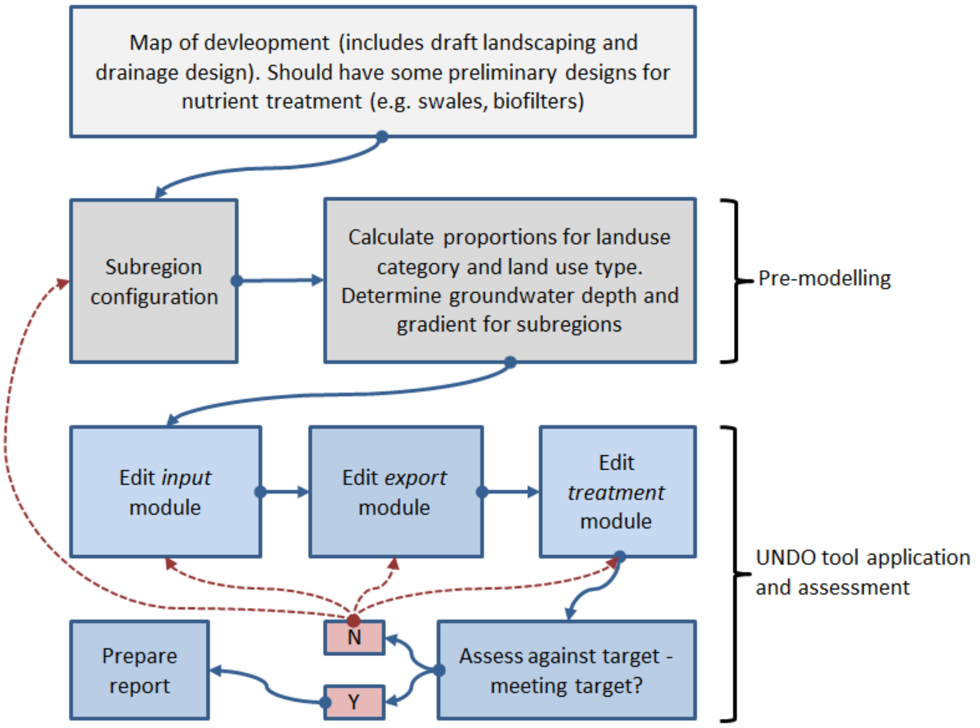


Figure 2-2: *Flow diagram outlining the approach for using the UNDO tool*

The data configuration can only be undertaken when the user has established an initial subregion configuration. It is common to use GIS software or spreadsheets to help in the data configuration which involves the following steps for each subregion:

1. Calculate the proportion of each land-use category within the subregion: Use the basic development design (see Section 4.3 for more information).

2. Calculate the proportion of each land-use type making up each land-use category: Use the draft landscaping design (see Section 4.4 for more information).

3. Calculate the average depth to (average) groundwater level: Use groundwater bore analysis, also required for a local water management strategy (see Section 5.1 for more information).

4. Calculate the groundwater gradient: Use groundwater bore analysis, also required for a local water management strategy (see Section 5.1 for more information).

5. Work out the soil type: There is a map interface in the UNDO tool to help with this (see Section 5.1 for more information).

6. Calculate the average fill depth if fill is used and estimate the approximate PRI of this fill if it is not standard Bassendean (white) or Spearwood (yellow) sands (this will need to be confirmed by laboratory analysis and submitted with the report – see Section 7).

7. Calculate the length of swales and living streams, if present, and the approximate area of biofilters, wetlands and dry ephemeral detention areas, if present.

The configured data is ready to be entered directly into the UNDO tool.

UNDO tool application and assessment

The UNDO tool is used to evaluate the nutrient design of the development, and is ready to use once the pre-modelling is complete. The data are entered into the input, export and treatment modules, respectively. When the treatment module is complete the user is provided with an export load of nitrogen and phosphorus.

This can be assessed against any development targets (which should have been identified in the district planning stage – as described in Section 2.1). If the targets are met, the current development nutrient management design is satisfactory and a report can be printed and sent to the relevant decision-making authorities (with the appropriate data attached. See Section 7 for the data that must be submitted with an UNDO report).

If the targets are not met, the development design may have to be altered and the user has the opportunity to edit the input, export or treatment modules in the UNDO tool, or alternatively to reconfigure the subregions (in which case pre-modelling will have to be re-done for the re-configured subregions). This process is repeated until nutrient targets are met.

3 Getting started

3.1 System requirements

The minimum hardware and software requirements for user's PCs are listed in Table 3-1. Computer administration rights are not required to install the software. However, administration rights will be required to install the .NET Framework 4.5, if the computer does not already have this software installed.

Table 3-1: *System requirements for the UNDO tool*

Attribute	Requirement
CPU Speed	2.2 GHz minimum or higher
Processor	Intel Pentium 4, Intel Core Duo or Xeon Processors; SSE2 (or greater)
Memory/Ram	2 GB or higher
Display Properties	24 bit colour depth
Screen Resolution	1024 x 768 recommended or higher at Normal size (96 dpi)
Swap Space	Detemined by the operating system, 500 MB minimum. The system will run more efficiently with at least 8 GB of free hard drive space
Disk Space	>1 GB
Video/Graphics Adaptor	64 MB RAM minimum, 256 MB RAM or higher recommended. NVIDIA, ATI and INTEL 24 bit capable graphics accelerator.
Network	Internet connection required
Operating systems	Compatible with Windows XP, Vista, 7, 8 and 10 (32 and 64 bit operating systems) and Macintosh. Cannot be used on tablets
Internet browsers	Compatible with Internet Explorer, Mozilla Firefox, Safari. Not compatible with Google Chrome or Microsfot Edge
Prerequisite software	.NET framework 4.0 and Microsoft Silverlight Plugin

3.2 Accessing the tool

The UNDO tool can be accessed via the Department of Water's internet site (http://www.water.wa.gov.au/planning-for-the-future/water-and-land-use-planning/undo-tool). Figure 3-1 shows the UNDO tool home screen, displayed when the link from the Department of Water webpage is clicked. If you have not used the UNDO tool before, the blue box will display 'Install UNDO tool'. Click on this box. If your computer does not have Microsoft .NET framework (Version 4.5) installed, this will automatically be installed (requires administration privileges).

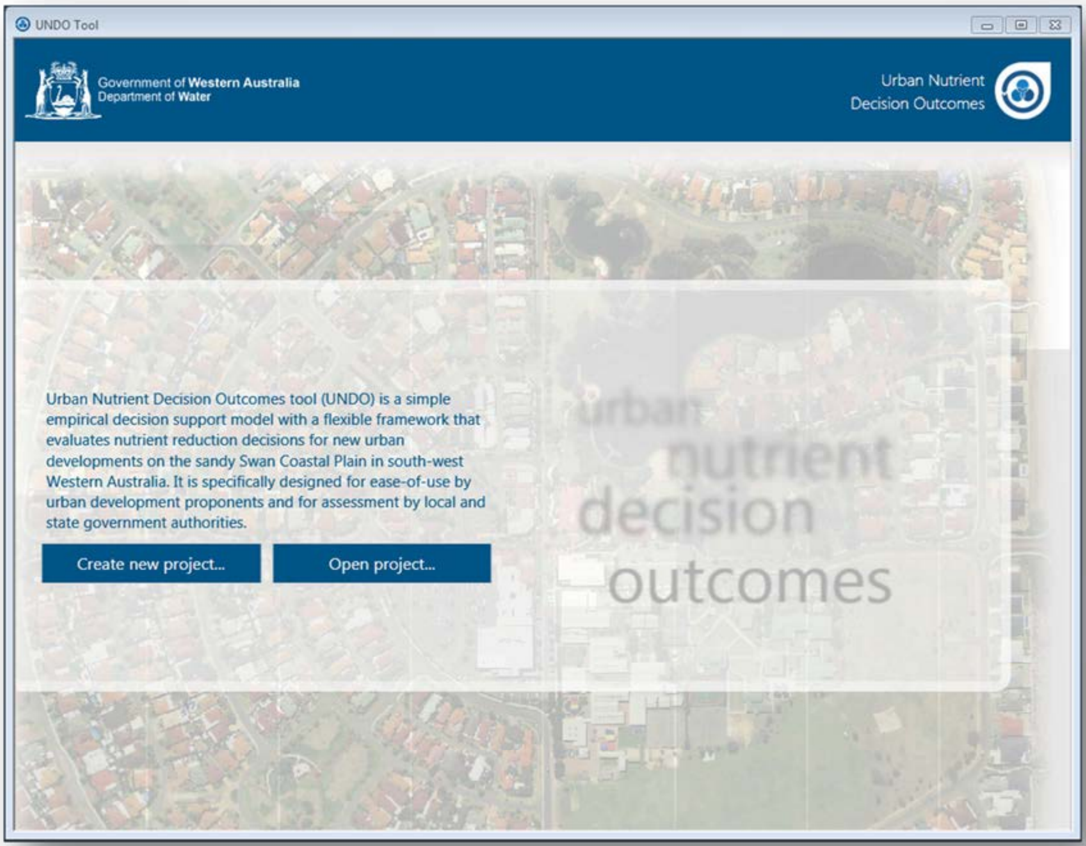


Figure 3-1: *UNDO tool home screen*

Once the UNDO tool is installed the “UNDO tool” Symbol will appear on the desktop:

Double-clicking this icon will launch the tool. Note that this is not a stand-alone program and a website is actually being launched.

3.3 UNDO tool support

Support for the UNDO tool is available between 0900 and 1700 hours (Western Australian standard time) on any day except Saturday, Sunday or a Western Australian public holiday. Support is available via email (undo@water.wa.gov.au or by phone (6364 7843). Users may be required to document bugs or issues for support, or to send .undo files to the UNDO tool team so issues can be identified efficiently.

3.4 A brief overview

Users will initially create a new project from the UNDO tool home screen. When this button is selected the 'project setup' panel is displayed. Some basic information is entered into the project setup panel, so the UNDO tool project can be pre-configured. This includes the name of the project, the total area of the development, and the number of subregions to be used initially (note that the users can add or delete subregions from within the UNDO tool project). Subregions are explained in detail (including a guide to configuring project into subregions) in Appendix A. The project setup panel is shown in Figure 3-2.

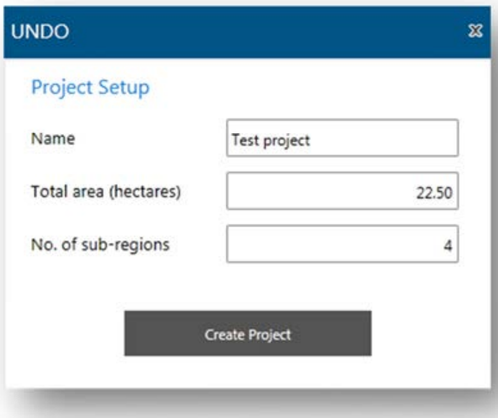


Figure 3-2: *UNDO tool project setup panel*

When users create a project, the UNDO tool interface will load, and be pre-configured with the area of the development, the name of the development and the number of subregions (which are initially set equally dividing the project area). When the 'create project' button is clicked, the UNDO tool interface will appear. The UNDO tool interface consists of four main pages (or *modules* as they are referred to in this document), and users can navigate between these pages to modify/update their project. Figure 3-3 shows the navigation ribbon that appears at the bottom of all modules.

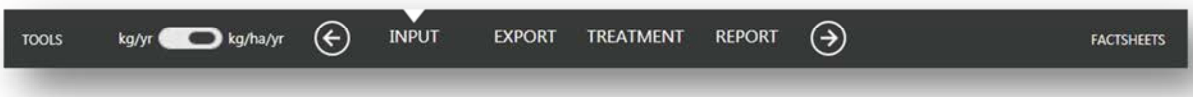


Figure 3-3: *Display of the ribbon at the bottom of the UNDO tool home-page*

Users can navigate to the next module or previous module by clicking on the arrows on the ribbon, or they can navigate directly to a module by clicking on the text. There is an option for UNDO to report in absolute terms (kg/yr) or in relative terms (kg/ha/yr). There is also a button for tools and for factsheets, which will be discussed in the next section. The four modules of the UNDO tool are summarised below.

Input module

The *input* module is where users configure the development. This page allows further division of the development into a series of 'subregions' (see Appendix A), and defines the subregions with respect to the land use within. The *input* module calculates the nutrient input (which is a function of the land use type configured) applied to the catchment. More information on the *input* module is provided in Section 4.

Export module

The *export* module calculates the amount of nutrient exported (conveyed by runoff associated with rainfall) from each subregion. This module calculates the mass of nitrogen and phosphorus exported from the land parcel, before it is routed through a drainage system and/or a series of structural treatments. The nutrient export quantity is dependent on soil type, drainage type, depth to groundwater, groundwater gradient, the presence of onsite sewerage disposal, and the amount of nutrient applied to the catchment. More information on the *export* module is provided in Section 5.

Treatment module

The *treatment* module allows users to input structural treatments. Users can add and configure structural treatments using a simple node-link set-up. This allows a treatment-train approach to modelling treatments, and a network of treatments can be developed. Structural treatments available in the UNDO tool include: biofilters, swales, living streams, constructed wetlands and dry/ephemeral detention areas. More information on the *treatment* module is provided in Section 6.

Report module

The *report* module automatically generates a project report that contains all the information outlined in the previous three modules, and provides a figure of the structural treatment network. The report will be sent to the decision-making authorities, together with a plan of the development and any required analytical test results.

The UNDO tool updates immediately so when any aspect of the tool is edited all parts of the tool are re-calculated, allowing users to easily see the impacts of the changes at both local and whole-of-development scale. More information on the *report* module is provided in Section 7.

3.5 Subregions

The basic building blocks of the UNDO tool are called *subregions*. The sum of all subregions in an UNDO tool's project will be equivalent to the total development area. A subregion represents the collective sum of portions of land within the development area. Subregions can represent a mixture of land categories (e.g. public open space, road reserve and urban residential) or they can represent a single land category. There is no limit to the number or size of the subregions that can be entered into an UNDO tool project.

Subregions are configured in the pre-modelling phase of an UNDO project (Figure 2-2). There are some basic rules and guidance recommended for dividing a development into subregions – these are outlined in *Appendix A: A guide to configuring subregions for the UNDO tool.*

3.6 Providing transparent information

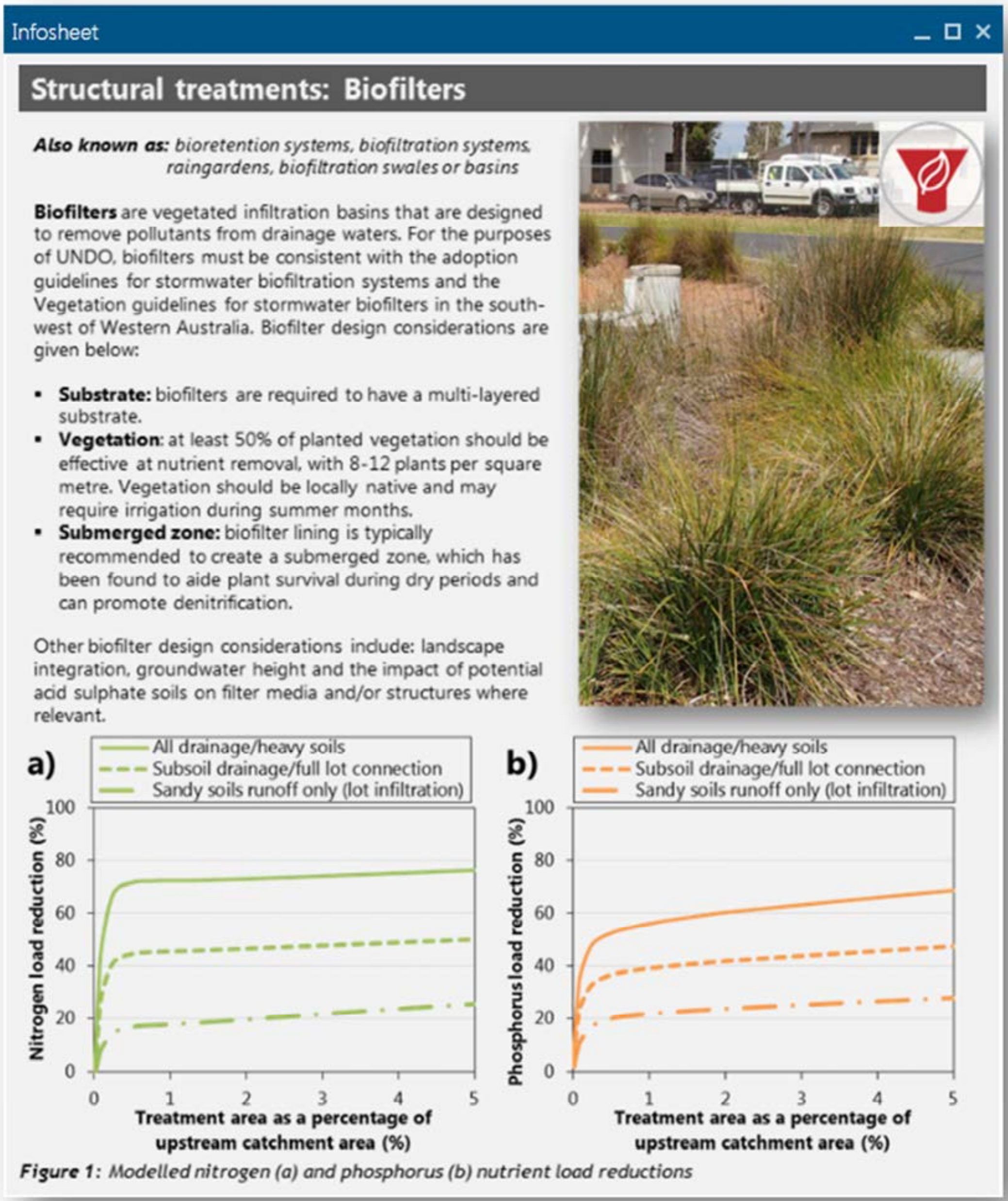
A primary objective of the design of the UNDO tool is to provide links to literature and publications for data and information used to produce all parameters and rates in the tool. The tool is built on a collection of the peer reviewed data, literature and research. This information is easily accessible from the UNDO tool interface. If a user feels that critical information is missing or incorrect (e.g. if a certain BMP is not available in the tool or if an input rate is not based on current or best quality data), the user can provide the Department of Water with an appropriate scientific reference (e.g. scientific report or peer reviewed journal article), and the information will be reviewed and considered for the next version of the UNDO tool.

More information on version updates and implementation of new data is provided in the Technical Manual, Section 7. Background information is accessible in three different formats through the UNDO tool's interface: information tabs, fact sheets and the help menu.

Information tabs ( )

Information tabs are provided to the left of each of the elements that the user enters in an UNDO tool project (including land-use types, treatments and export attributes). The information tab will either provide a brief explanation of the element when the user hovers the cursor over the tab, or if the tab is clicked it will display an *information sheet. Information sheets* provide a brief summary of the definition of the particular element, and information or data used for that element to generate a nutrient input, export, or treatment.

The *information sheets* have a link to the *fact sheets* or to the *help menu* for more detailed information and references. An example of the *information sheet* for biofilters (a structural treatment) is shown in Figure 3-4.



Infosheet

Structural treatments: Biofilters

Also known as: *bioretention systems, biofiltration systems, raingardens, biofiltration swales or basins*

Biofilters are vegetated infiltration basins that are designed to remove pollutants from drainage waters. For the purposes of UNDO, biofilters must be consistent with the adoption guidelines for stormwater biofiltration systems and the Vegetation guidelines for stormwater biofilters in the south-west of Western Australia. Biofilter design considerations are given below:

- **Substrate:** biofilters are required to have a multi-layered substrate.
- **Vegetation:** at least 50% of planted vegetation should be effective at nutrient removal, with 8-12 plants per square metre. Vegetation should be locally native and may require irrigation during summer months.
- **Submerged zone:** biofilter lining is typically recommended to create a submerged zone, which has been found to aide plant survival during dry periods and can promote denitrification.

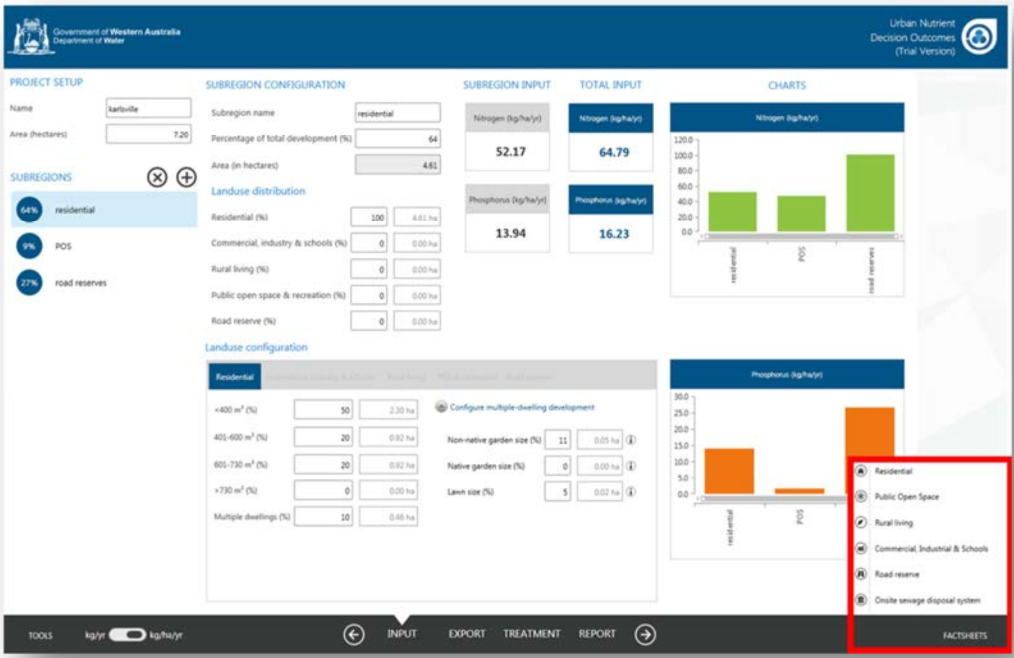
Other biofilter design considerations include: landscape integration, groundwater height and the impact of potential acid sulphate soils on filter media and/or structures where relevant.

Figure 1: *Modelled nitrogen (a) and phosphorus (b) nutrient load reductions*

Figure 3-4: *Information sheet for biofiters*

Fact sheets

Users can access *fact sheets* using the menu at the bottom right of the UNDO tool ribbon (Figure 3-5a). *Facts sheets* provide a summary of the data/information used in the UNDO tool and relevant studies and references used (Figure 3-5b). They are detailed (between 2 and 10 pages long) and provide a list of relevant literature and studies, a summary of each of these studies, and justification for the rates adopted in the UNDO tool.



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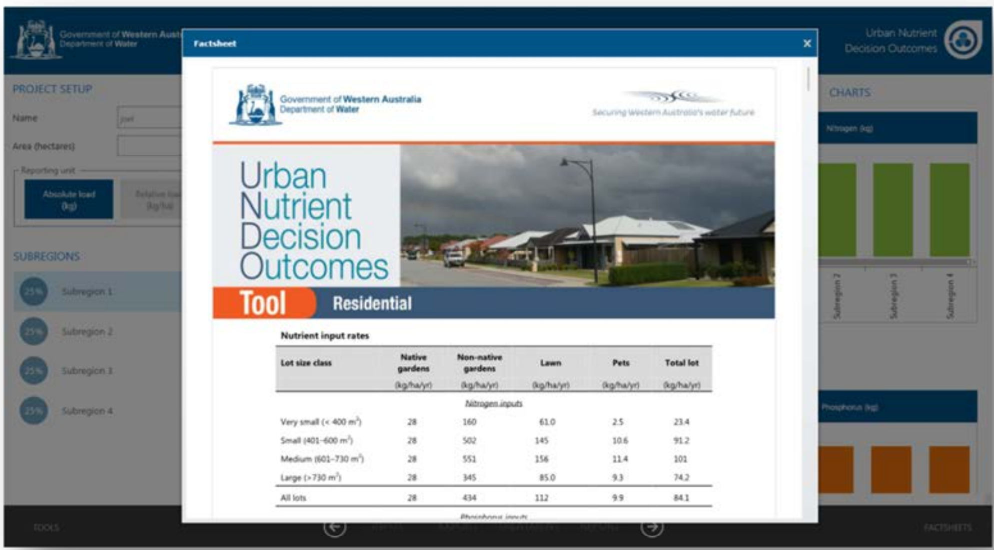


B

***Figure 3-5:** a) the fact sheet menu bar on the UNDO interface and b) example of an UNDO tool fact sheet*

Help menu

The UNDO help file is available in the tools menu bar, located on the bottom left of the navigation ribbon (Figure 3-3). The help file is typical for Microsoft Windows applications, and provides an online version of this user guide, with search functionality and indexing. The help window is displayed in Figure 3-6.

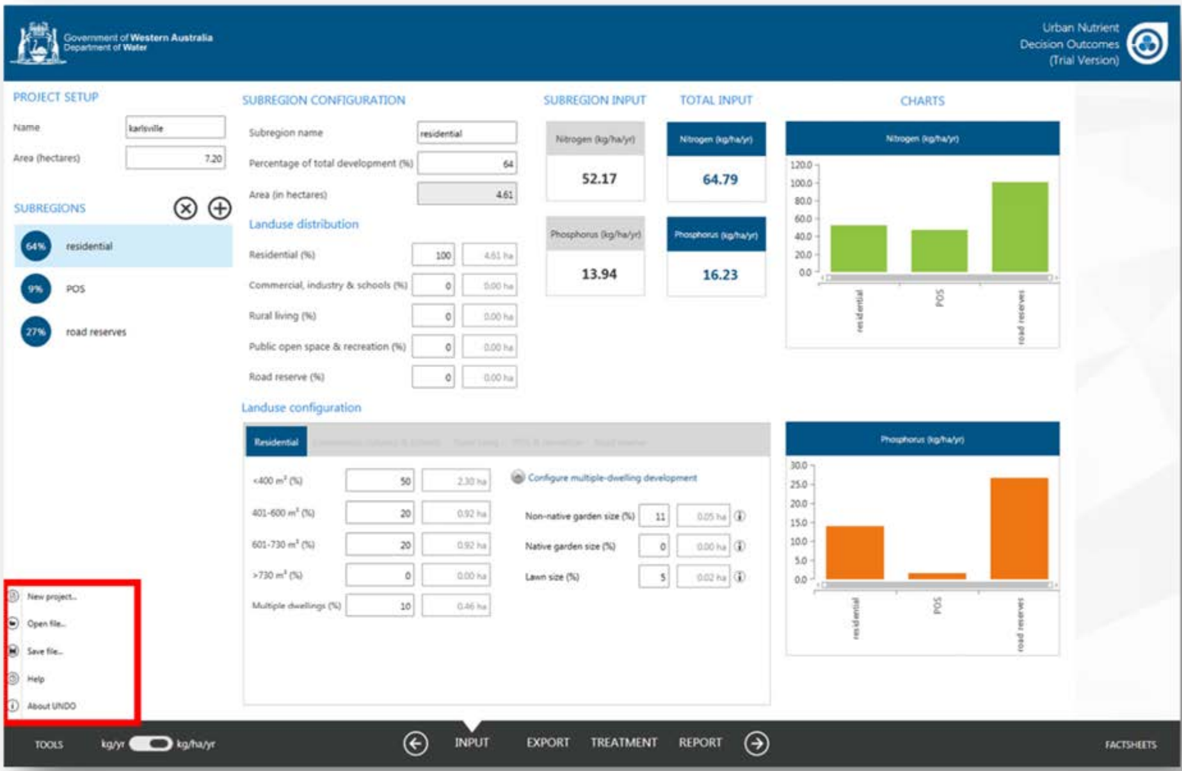


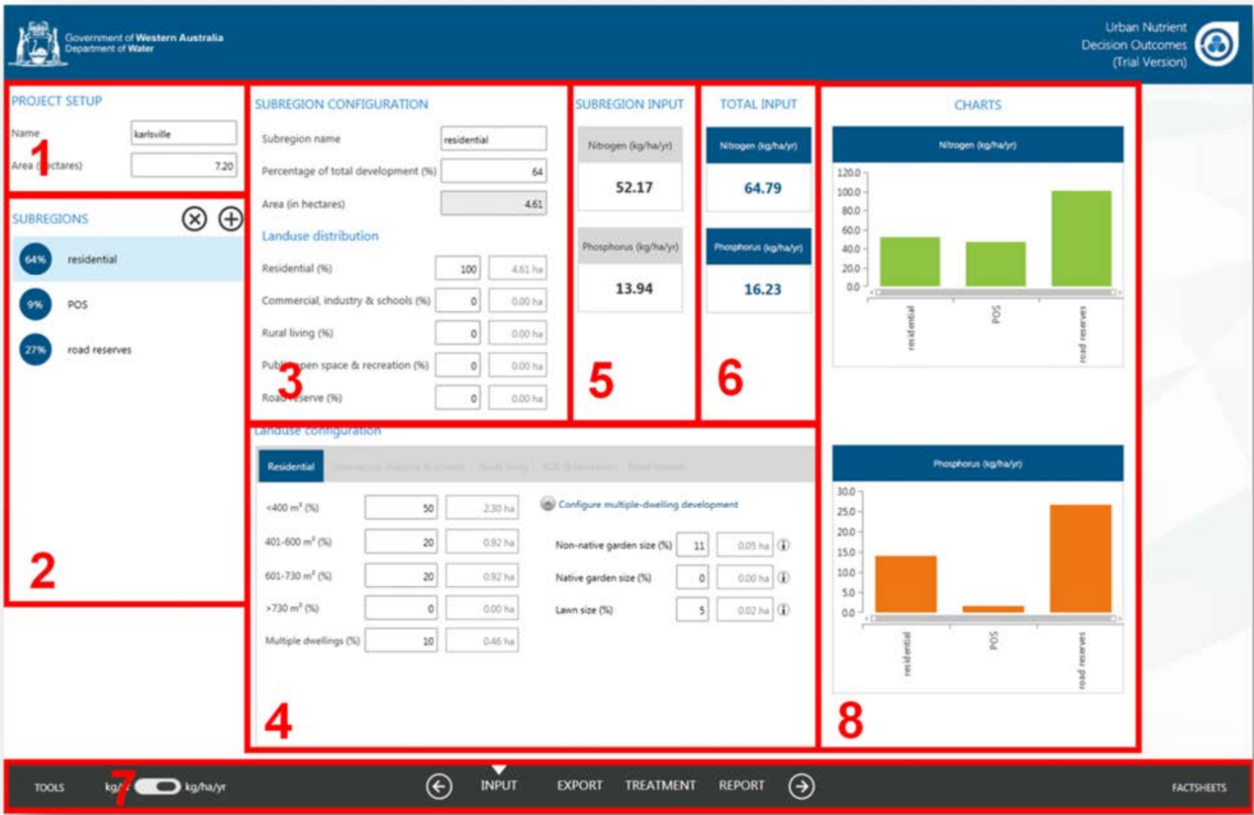
Figure 3-6: *Location of the help menu in the UNDO tool*

3.7 Loading and saving project files

Users can save an UNDO project or load existing project files from the 'tools' menu located on the UNDO tool ribbon (Figure 2-2). The UNDO tool files are saved with the postfix .undo. The files are binary and generally quite small in size (< 1 MB) so they can be emailed or sent to other users or decision-making authorities when required. It is important to note that saved files may only be compatible with a current version of the UNDO tool, and users are encouraged to print reports of the development areas so that information is not lost if an updated version of the tool is released. Users on the UNDO tool email list will be notified of upcoming releases and given warning to save the information as reports before the .undo files become redundant.

4 Page 1: Inputs

When a user creates an UNDO project (using the project setup panel) or if a user loads an existing project, the UNDO tool interface will open and display the *input* page. The *input* page is the first page a user will populate, and it calculates the quantity of nitrogen and phosphorus applied to the development area. The configuration of the *input* page and a description of all of its components are shown in Figure 4-1. The components of the *input* page are described below in the following sections.



1: Project setup
2: Subregion summary
3: Subregion configuration
4: Land use configuration
5: Subregion summary
6: Development summary
7: Navigation ribbon
8: Summary charts (scroll right)

***Figure 4-1:** Configuration of the UNDO tool input page*

4.1 Project setup

This panel is pre-configured from the project setup which is displayed when a user creates a project. The project setup can be adjusted any time during the project development and includes the name of the UNDO project (this can be the name of the development or a version of the development being tested with a particular instance of the UNDO tool) and the total area of the development (in hectares). It also includes the reporting units for the project, which can be in absolute load (kg/yr) or relative load (kg/ha/yr). The default is for absolute load.

4.2 Subregion summary

This panel shows each of the subregions that make up the development (see Appendix A for more information on subregions, including guidance for users to develop their UNDO project into a series of subregions), and a button to create extra subregions. The list of subregions displays the name given to the subregion (which can be edited in the 'subregion configuration' panel) and the percentage of the development area occupied by the subregion displayed in small blue circle icon. The subregion list is 'clickable', so users can click on a particular subregion and it will be available to edit in the subregion configuration and land-use configuration panels.

Subregions can be deleted or added to the project using the ⊗ ⊕ buttons at the top of the panel.

4.3 Subregion configuration

The subregion configuration panel allows the user to adjust the size and the types of land use, the name and percentage of the total development area. The subregion area (in hectares) is shown but is not editable. There are five land-use categories to choose from:

- Residential
- Commercial, industrial and schools
- Rural living
- Public open space & recreation
- Road reserve

A detailed description of each land use is provided in Section 4.4. Rural land-use types are not available in the UNDO tool, as the tool is developed specifically for urban developments. Guidance for the appropriate configuration is provided in *Appendix A: A guide to configuring subregions in the UNDO tool.*

4.4 Land-use configuration

The land-use configuration panel allows users to add further detail to the land-use definitions within the five land categories. This process assigns a nutrient input rate to a particular land use. The five categories are further broken down to land-use types which are described below.

Residential

By definition, residential land uses include all buildings with permanent accommodation for people. This category mostly comprises single dwellings, but can include the residential component of mixed-use dwellings, aged persons accommodation, group dwellings and communal properties (which are entered under the category ‘multiple-dwellings’). The UNDO tool further divides these lots into four categories (< 400 m^2, 400–600 m^2, 601–730 m^2, and 730–2000 m^2, or strata (multiple-dwelling developments). The setup of the ‘Residential’ table of the land-use configuration panel is shown in Figure 4-2.

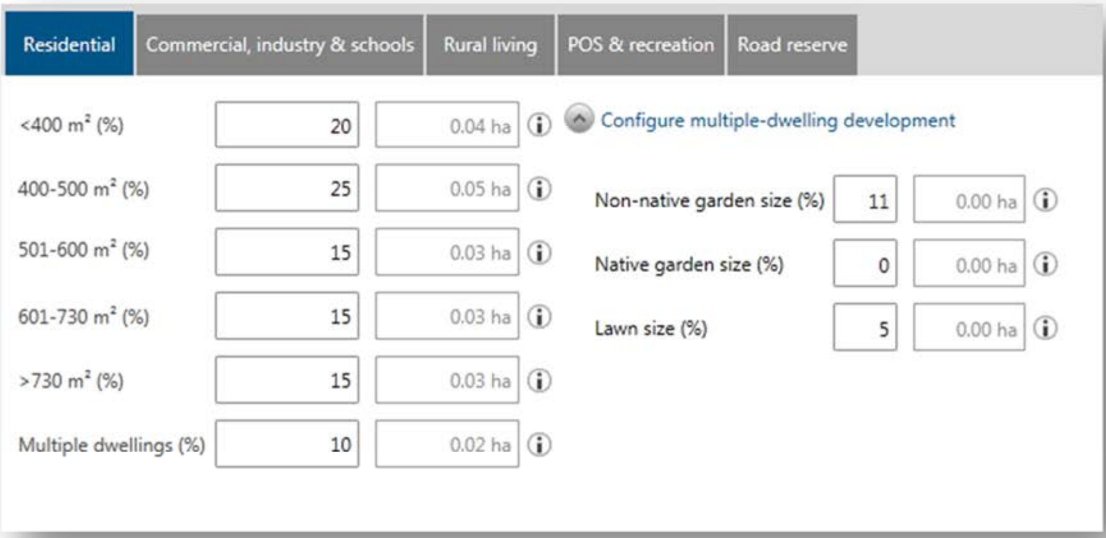


***Figure 4-2:** Residential tab from the UNDO tool’s land-use configuration panel*

The lot size categories are based on analysis that was part of the Department of Water’s urban nutrient survey (Kelsey et al. 2010), which indicated that dwellings of different sizes apply different fertiliser rates (for more information see the UNDO Technical Manual, Appendix B). The average garden size and lawn area for each of these lot size categories were also derived from this document, and are fixed (i.e. the user cannot adjust these values). The average garden size, lawn size, and nutrient input rates for each of the residential categories is shown in Table 4-1.

There are some instances where residential lots will be greater than 2000 m^2 (i.e. when the R-code is R2–R5 lot sizes will be 2000–5000 m^2). Although these lots are zoned ’residential’, for the purpose of the UNDO tool they are to be placed in the ‘Rural living’ land category.

Table 4-1: Average lawn size, garden size and nutrient input rate for residential land-use categories

Land-use category	Average garden size (m^2)	Average lawn size (m^2)	N input (kg/ha/hr)	P input (kg/ha/yr)
Residential, < 400m^2	33	16	23.4	6.9
Residential, 400–500m^2	55	52	67.9	17.1
Residential, 500–600m^2	65	91	98.6	26.4
Residential, 601–730m^2	78	115	101.0	25.6
Residential, 730–2000m^2	123	189	74.2	18.0

The user is required to enter the percentage of residential area within that particular lot size-range. Aged persons accommodation, group dwellings or communal properties, if entered, are placed in the ‘multiple-dwellings’ category. The UNDO tool has an option for the user to configure these developments so they can be landscaped to provide a limited size of non-native and native garden area. If this option is chosen, the user must provide evidence that this configuration will be upheld during the development stage of the project – otherwise default values should be used. The default for this category is for the same average percentage of garden and lawn size as for residential lots below 400 m^2 (Table 4-1).

Commercial, industry and schools

This category includes commercial buildings, offices, schools, public buildings, heavy and light industrial areas. The design of the ‘Commercial, industry and schools’ tab for the UNDO tool is shown in Figure 4-3.

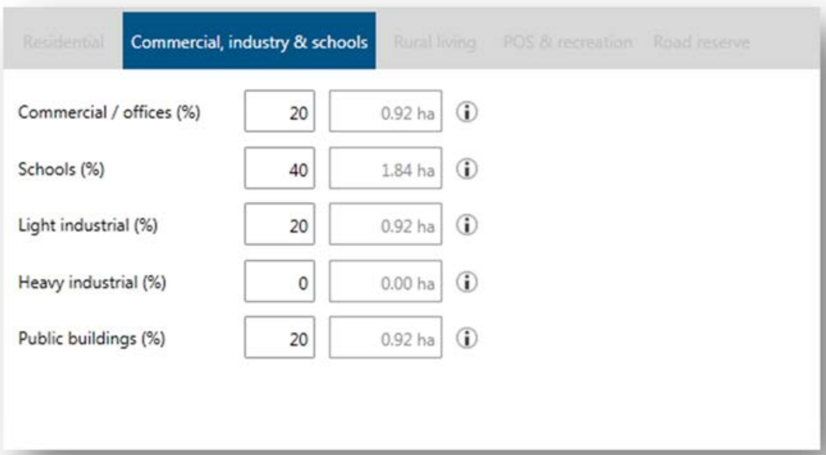


Figure 4-3: Commercial, industry and schools tab from the UNDO tool's land-use configuration panel

The user assigns a proportion of the total 'Commercial, industry and schools' area to one of five subcategories, each of which has assigned nutrient application rates:

- **Commercial/offices:** refers to commercial and service businesses such as shops, banks, post offices, medical centres, childcare centres, service stations, car showrooms and sales yards, hotels, taverns, restaurants. The shops can be small individual premises along a street or large shopping centres. The offices may be surrounded by parkland or not. The nutrient input rates were calculated by analysing aerial photography of commercial/office areas to determine relative areas of lawn, garden and impervious surface, so that lot input rates could be estimated from fertilisation rates to garden beds and lawns (N input = 26.4 kg/ha/yr, P input = 6.4 kg/ha/yr).
- **Schools:** refers to kindergartens, primary schools, high schools and universities. Although small schools such as parent-run kindergartens may have very different garden and ground maintenance compared with large private schools they have been lumped together. Note that playing fields for large schools will generally be included in the *active turf* classification. The nutrient input rates were decided by analysing aerial photography of schools to assign relative areas of passive and active turf, garden and impervious surface, so that lot input rates could be estimated from fertilisation rates to turf and garden beds (N input = 97.7 kg/ha/yr, P input = 19.1 kg/ha/yr).
- **Light industrial:** refers to small manufacturing and service facilities such as food processing, car servicing, joinery and other trades, and storage and distribution sites. The nutrient input rates were selected by analysing aerial photography of light industrial areas to assign relative areas of lawn, garden and impervious surface, so that lot input rates could be estimated from fertilisation rates to garden beds and lawn areas (N input = 14.3 kg/ha/yr, P input = 2.9 kg/ha/yr).
- **Heavy industry:** refers to areas such as the Kwinana Industrial Area and the Australian Marine Complex (Henderson). These areas host heavy industries such as alumina smelters, power-production plants, mineral and oil refineries, steel works, fertiliser works and ship-building industries. These land uses will generally not be part of urban developments modelled with the UNDO tool. Nutrient inputs are generally limited to small areas of gardens that beautify entrances to offices and other sites. Nutrient input estimations for heavy industries are taken to be the same as for light industries (N input = 14.3 kg/ha/yr, P input = 2.9 kg/ha/yr).
- **Public buildings:** refers to council and shire offices, libraries, hospitals, fire stations, churches and community centres, art galleries and museums and function centres. *Public buildings* generally have only small areas of garden. Nutrient input rates for *public buildings* were assumed to be the same as for *commercial/offices* (N input = 26.4 kg/ha/yr, P input = 6.4 kg/ha/yr).

Rural living

The rural living category is used loosely in the planning industry, but for the purposes of the UNDO tool, this includes residential lots larger than 2000 m^2 and smaller than 2 ha. They comprise low-density residential subdivisions and rural allotments created primarily for residential purposes, excluding dwellings associated with bona-fide agricultural holdings. In planning terms, rural living can include (but are not limited to) the following zones:

- **Rural-residential:** Land is used for residential purposes in a rural setting which provides for alternative residential lifestyle and which seeks to preserve the amenity of such areas and control land-use impacts.
- **Rural smallholdings:** Land is used for minor rural pursuits, hobby farm, conservation lots and alternative residential life style purposes where part-time income from cottage industries, home occupation and use of the land for agriculture may be derived.
- **Special residential:** Allows for lots of a size that will offer a style of spacious living at densities lower than those characteristic of traditional single residential developments: between 2000 m^2 and one hectare. Generally in areas that have already been zoned ‘urban’.
- **Urban residential (R2–R5):** Where the R-code is R2–R5 lot sizes will be 2000–5000 m^2, and although these have a residential zoning, for the purpose of UNDO they are to be placed in the ‘Rural living’ category.

Rural living dwellings are likely to have onsite sewage disposal systems. They may have some rural activities on them (e.g. horses, small orchards, or some livestock). It is common for rural living precincts to have restrictions on the title or within the planning scheme, which excludes various activities from being allowed on the lot. The design of the ‘Rural living’ tab for the UNDO tool is shown in Figure 4-4.

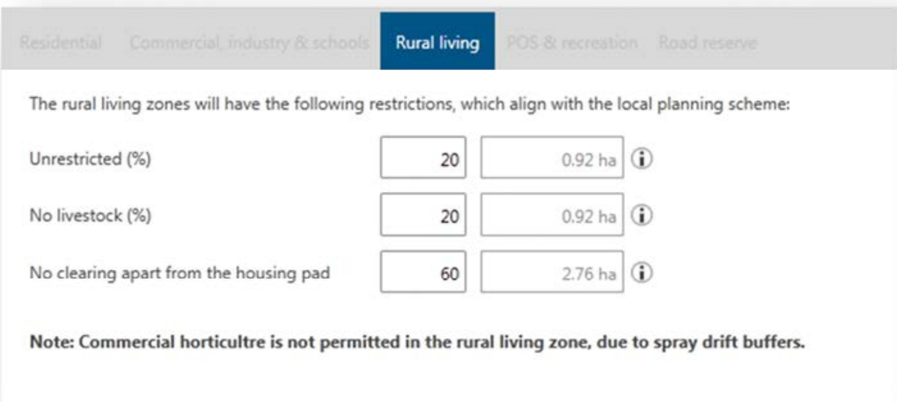


***Figure 4-4:** Rural living tab from the UNDO tool’s land-use configuration panel*

Three levels of restrictions can be placed on rural living lots within the UNDO tool:

1. **Unrestricted:** Unrestricted rural living lots are permitted by local government authorities to rear livestock, which may include horses, sheep, cows, goats, alpacas or other animals. They may be kept as pets or as a small commercial enterprise. Nutrient inputs are from imported feed, fertilisation and nitrogen fixation. The Department of Agriculture and Food WA have done extensive farm-gate nutrient balance studies in the south-west of WA. Unrestricted rural living lots are assumed to have the same nutrient input rates as horses (N input = 79.5 /ha/yr. P input = 13.2 kg/ha/yr).
2. **No livestock:** This land-use classification refers to rural developments that have livestock and horse-rearing restrictions. Such developments are assumed to be permitted to undertake other forms of non-intensive agriculture, such as orchards, viticulture and small-scale horticulture (N input = 6.0 /ha/yr, P input = 4.1 kg/ha/yr).
3. **No clearing apart from the housing pad:** This land-use classification refers to highly restricted developments within native forest. Clearing is only permitted for the house footprint and fire breaks. No fertilisation is assumed apart from the nutrient inputs of native vegetation and from atmospheric deposition (N input = 9.23 /ha/yr, P input = 0.15 kg/ha/yr).

Note: nutrients from onsite sewage disposal are accounted for in the nutrient export section.

Any restrictions placed on rural living developments in the UNDO tool must be clearly marked on the development plan, and the process to enact the restrictions must be described in the corresponding local or urban water management strategy. This can include modifications to the planning scheme, or restrictive covenants on titles.

Commercial annual horticulture has an extremely high nutrient input rate (much higher than horses) but it is assumed that commercial horticulture is not allowable in urban developments, due to recent Department of Health policy on spray drift buffers (Department of Health 2012). Annual horticulture is not considered in the ‘Rural living’ category.

Public open space & recreation

This category includes land set aside for unrestricted recreational activities within an urban development. According to development control policy 2.3 (WAPC 2002), a minimum of 10 per cent of the developable area must be set aside for public open space in residential developments within Western Australia. Land uses include gardens, ovals, bicycle paths, remnant native vegetation, public golf courses, stormwater management systems and water bodies which provide a recreational amenity. For the purposes of the UNDO tool, public open space may include some restricted land uses, including golf courses, bowling greens, and sports stadiums. The design of the ‘Public open space’ tab of the land-use configuration panel is shown in Figure 4-5. Landuses that have not fertiliser applied directly are assigned an atmospheric deposition rate of 5.23 kg/ha/yr N and 0.15 kg/ha/yr P. A literature review and results of measured data on atmospheric deposition can be found in the “atmospheric deposition” fact sheet.

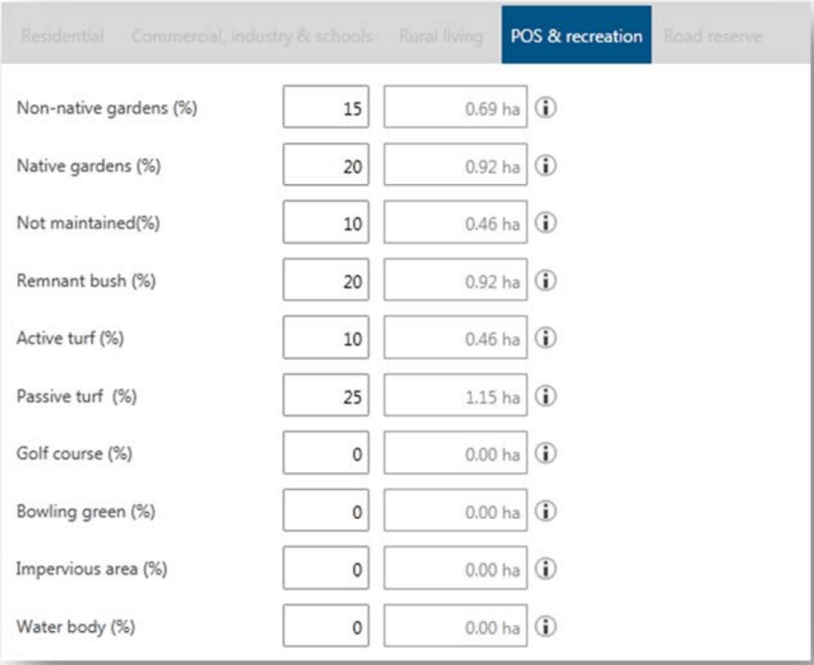


Figure 4-5*: Public open space & recreation tab from the UNDO tool's land-use configuration panel*

The '*Public open space & recreation'* land-use category has 10 subcategories:

1. **Non-native gardens:** Areas of public open space planted with species that are not Australian natives. These rates have been derived from a survey of the fertilisation practices of 20 local government authorities in the Perth metropolitan area by the South East Regional Centre of Urban Landcare (N input = 77 kg/ha/yr, P input = 24 kg/ha/yr).
2. **Native gardens:** Areas of public open space planted with native species. Inputs are from fertilisation and fixation. These inputs rates are those estimated for residential native gardens. The rates for native gardens in POS maintained by local and state government authorities may be different and more information is being sought to update these rates (N input = 28.0 kg/ha/yr, P input = 0.9 kg/ha/yr).
3. **Not-fertilised:** Areas of POS that are not maintained or deliberately not fertilised. POS that is non-maintained remnant native bush is classified as Remnant Bush. They are assigned atmospheric fertilisation rates only (N input = 5.23 kg/ha/yr, P input = 0.15 kg/ha/yr).
4. **Nature:** Areas of remnant native vegetation are not irrigated or fertilised and are assumed to have nitrogen input from fixation by some native plants and atmospheric deposition (N input = 9.23 kg/ha/yr, P input = 015 kg/ha/yr).

5. **Sport:** Playing fields and sporting ovals. These areas contain well-maintained grass that is irrigated and fertilised. Active turf does not include golf courses and bowling greens, which have their own categories (N input = 75 kg/ha/yr, P input = 6 kg/ha/yr).
6. **Recreation:** Grassed areas used for passive recreation such as picnicking and walking. These areas are generally irrigated and fertilised but not as intensively as active turf (N input = 66 kg/ha/yr, P input = 2 kg/ha/yr).
7. **Golf course:** Different fertilisation rates apply for fairways, tees and putting greens. The values given here are the weighted averages for the whole golf course (N input = 159 kg/ha/yr, P input = 6.8 kg/ha/yr).
8. **Bowling green:** In urban areas these are generally more intensively irrigated and fertilised than playing fields, sporting ovals and golf courses (N input = 209 kg/ha/yr, P input = 5.3 kg/ha/yr).
9. **Paved area:** Areas of public open space with a paved surface, such as car parks, cycle paths, hard playing surfaces and buildings. These areas have atmospheric inputs only (N input = 5.23 kg/ha/yr, P input = 0.15 kg/ha/yr).
10. **Water body:** Refers to ornamental ponds, constructed and natural wetlands, and lakes, rivers and estuaries. These areas have atmospheric inputs only (N input = 5.23 kg/ha/yr, P input = 0.15 kg/ha/yr).

Road reserve

This category includes the development areas set aside for roads and road verges. Typically this includes roads, bicycle paths, foot paths, verges, median strips and public transport corridors (for the purpose of the UNDO tool this includes rail corridors). The design of the ‘Public open space’ tab of the land-use configuration panel is shown in Figure 4-6. Six of the subcategories in the road reserve tab have the same nutrient inputs as their equivalent land use in the ‘Public open space’ (POS) category:

1. **Roads** – same as POS – impervious area
2. **Road verge** – paved: same as POS – paved area
3. **Road verge** – native garden: same as POS – native garden
4. **Road verge** – non-native garden: same as POS – non-native garden
5. **Road verge** – turf: same as POS – recreation
6. **Road verge** – not fertilised: same as POS – non fertilised

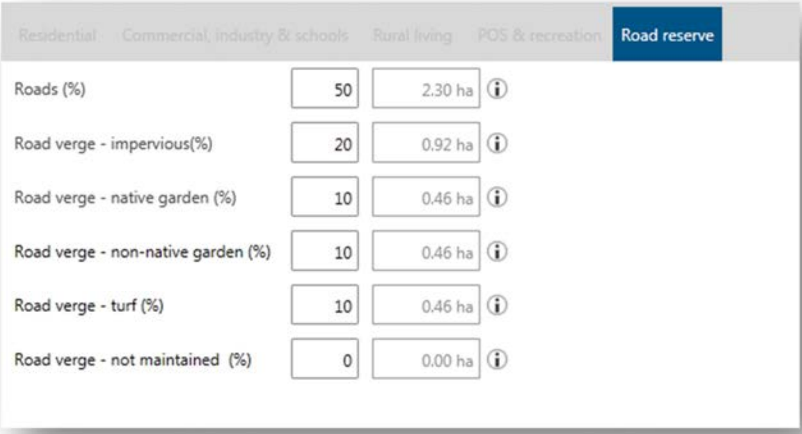


***Figure 4-6**: Road reserve tab from the UNDO tool's land-use configuration panel*

4.5 Input summary charts

Charts for the nutrient inputs from each of the subregions are shown in a panel on the far left of the UNDO tool's input page (if the screen resolution is low or the tool interface is not maximised, the user may need to scroll left to view the charts). An example of the charts for four subregions is shown in Figure 4-7.

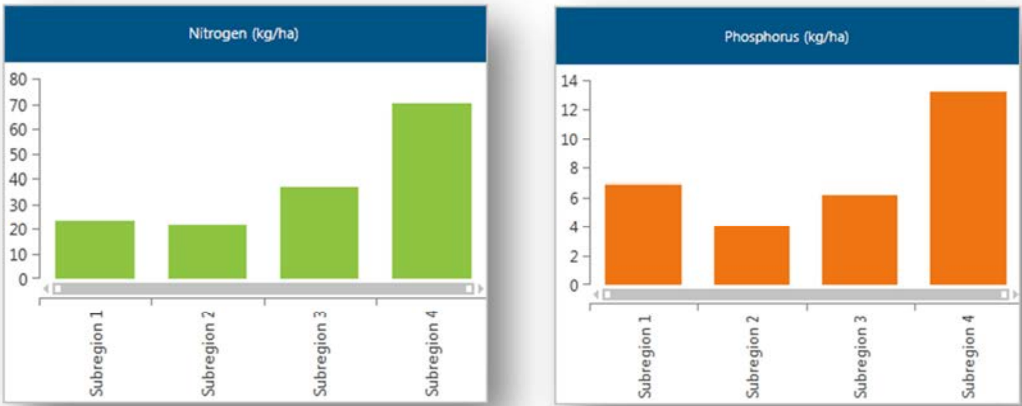


***Figure 4-7:** Nutrient input summary charts*

The charts are immediately updated when changes are made on the input page. The charts will switch from reporting in absolute load (kg/yr) to relative load (kg/ha/yr) when the load reporting button (located on the UNDO tool ribbon) is clicked:

The charts provide the user with a clear visual comparison of the subregions that are producing the largest loads and will help target subregions for treatment or remediation, and provide better understanding of the development's nutrient inputs.

4.6 Error reporting

The UNDO tool's *input* page provides error reporting functionality. This ensures that:

- The sum of all subregions is equal to the development area.
- The sum of all land-use types for a particular subregion is equal to the total area of the subregion.
- The sum of the land-use components within a land-use type is equal to the area of that particular land-use type.

An example of the error reporting functionality is displayed in Figure 4-8.

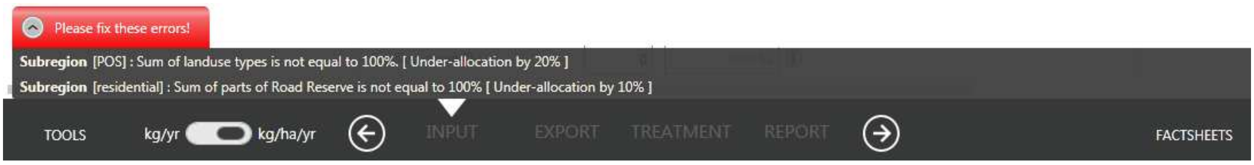


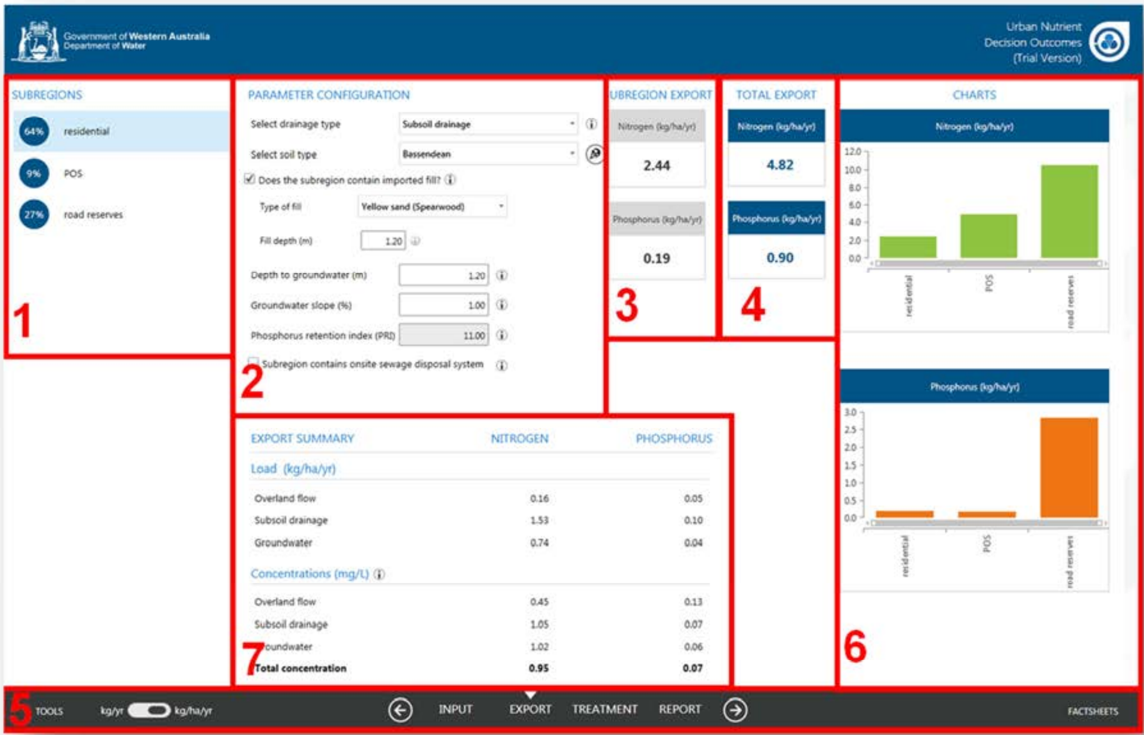
Figure 4-8: *Example of the UNDO tool error reporting on the input page*

The error reporting provides a list of the errors, which includes the name of the subregion (Subregion 1 in the example above), where the error occurs, and the quantity of the error. In the example above, the land-use types are 'over-allocated' by 20%, so the user has put a total of 120% of the subregion area into the various land-use types (in the subregion configuration panel). Also the user has 'Under-allocated' the land-use components of the 'Commercial, Industry and Schools' land-use type (in the land-use configuration panel), so the sum of the land-use components in this land-use type would currently be 80%.

The user will not be able to navigate away from the Input page until all errors are fixed. The list of errors can be quite long, and can obstruct the view of the UNDO interface in some cases, so there is an option to show and hide this list of errors by clicking on the  button at the top of the error list.

5 Page 2: Exports

The second page of the UNDO tool is the *export* page, which calculates the amount of nutrient exported from the catchment at an 'edge-of-lot' scale. This part of the tool calculates the quantity of nutrient exported from the land parcel before it is routed through a drainage system and/or a series of treatment devices. The configuration of the export page is shown in Figure 5-1.



1: Subregion list and summary

2: Export configuration

3: Subregion export load

4: Development export load

5: Navigation ribbon

6: Summary charts

7: Indicative loads and concentrations

Figure 5-1*: Configuration of the UNDO tool - Export page*

5.1 Export configuration

The export configuration panel is shown in Figure 5-2. This is the only section of the export page that the user is required to complete, and provides subregion details of drainage type, soil type, fill depth, depth to groundwater, phosphorus retention index (PRI) of any imported fill and details of onsite sewage disposal systems if they are present. Each of the options displayed on the panel is detailed below.

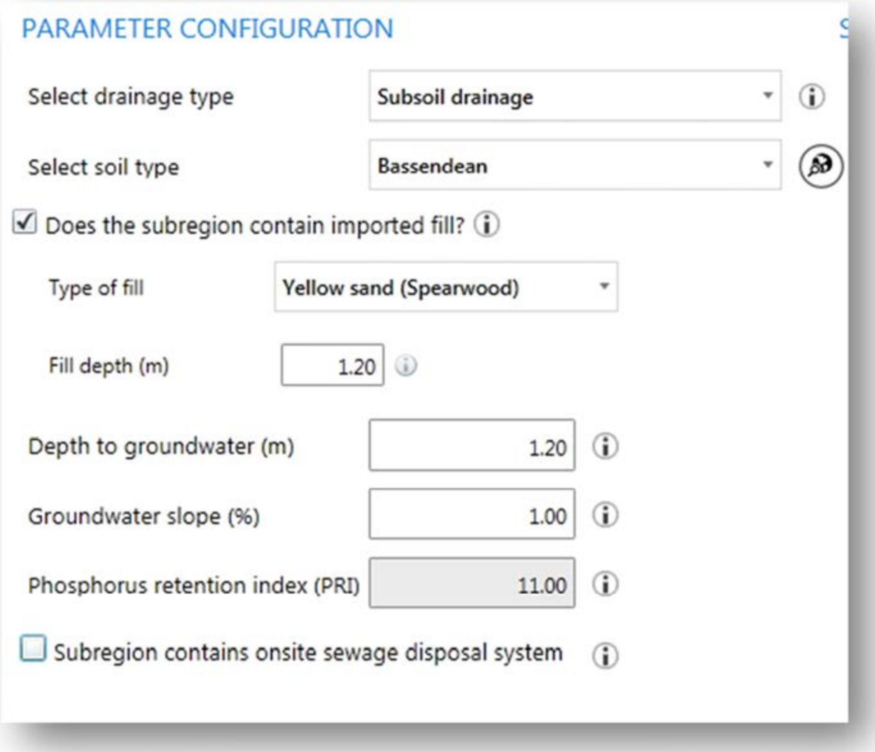


***Figure 5-2:** The export configuration panel of the Export page*

Select drainage type

Six drainage types can be selected in the UNDO tool. Conceptual diagrams for each of these drainage types for urban lots, public open space (POS) and road reserves is shown in Figure 5.3. The six drainage types are outlined below:

- **Infiltration:** Infiltration is common on the sandy Swan Coastal Plain, where there is a large depth to groundwater (generally greater than 3 metres) and subsoil drains or open channel drains are not required to control groundwater levels. Infiltration drainage systems do not contain any stormwater pipes, and all rainfall (up to the first 15mm of a rainfall event), is infiltrated on site. Very little runoff is exported from infiltration drainage systems, as most of stormwater is infiltrated deep into the soil profile, where it is exported via groundwater.

- **Open channel drains:** Open channel drains are common on the Sandy Swan Coastal Plain where groundwater levels are controlled by open channel drains, but subsoil drains are not used. This is common for rural living developments, where the house pad is raised, but other parts of the urban allotment may become waterlogged in Winter and Spring months. It is also a common drainage type for public open space in developments that use living streams as drainage mechanisms.

- **Piped/overland drainage:** Piped or overland drainage is common in heavier soils. It is important to note that *overland drainage* in this typology means that the water will be conveyed overland in small rainfall events (up to the first 15mm of a rainfall event). It is recognised that all drainage systems will have some overland drainage in rainfall events larger than the first 15mm of a rainfall event. Overland drainage is common on heavier soils in the Darling Scarp, east of the Swan Coastal Plain, or on the Blackwood Plateau, south of the Swan Coastal Plain. Piped drainage is also common in road reserves on the sandy sections of the Swan Coastal Plain, where pit-and-pipe systems are used to convey runoff (this commonly occurs in conjunction with infiltration and/or subsoil drainage systems which are used to drain the urban allotments, and developments need to be divided into separate subregions to account for the different drainage types, see Appendix B for details).

- **Subsoil drainage:** Subsoil drainage occurs on the Swan Coastal Plain where small rainfall events are infiltrated on site, but the groundwater level is controlled using subsoil drains. This drainage typology is associated with high groundwater tables. On clay or duplex soils (such as Guildford Clays and Pinjarra soils type), subsoil drainage is common, and sand fill is imported to separate the groundwater table from the building footings. Subsoil drainage is generally associated with urban residential lots only, and is less common in road reserves and public open space. However, subsoil drainage is increasingly being used to control groundwater levels in active turf (sporting grounds, ovals and playing fields).

- **Subsoil – partial lot connection:** Subsoil drainage with partial lot connection occurs on urban allotments where not all of the first 15mm is infiltrated at site (usually due to constraints on block size and location of infiltration systems). Therefore more water will be exported through runoff, and less water will be infiltrated to the groundwater. UNDO assumes that urban lots with partial lot connection will infiltrate the first 7.5mm of rainfall. Subsoil drainage with partial lot connection is not associated with public open space or road reserves.

- **Subsoil – full lot connection** Subsoil drainage with full lot connection occurs on urban allotments where no water is infiltrated at site (usually due to constraints on block size and location of infiltration systems). Therefore significantly more water will be exported through runoff, and less water will be infiltrated to the groundwater. Subsoil drains are used to control groundwater levels. Subsoil drainage with full lot connection is not associated with public open space or road reserves.

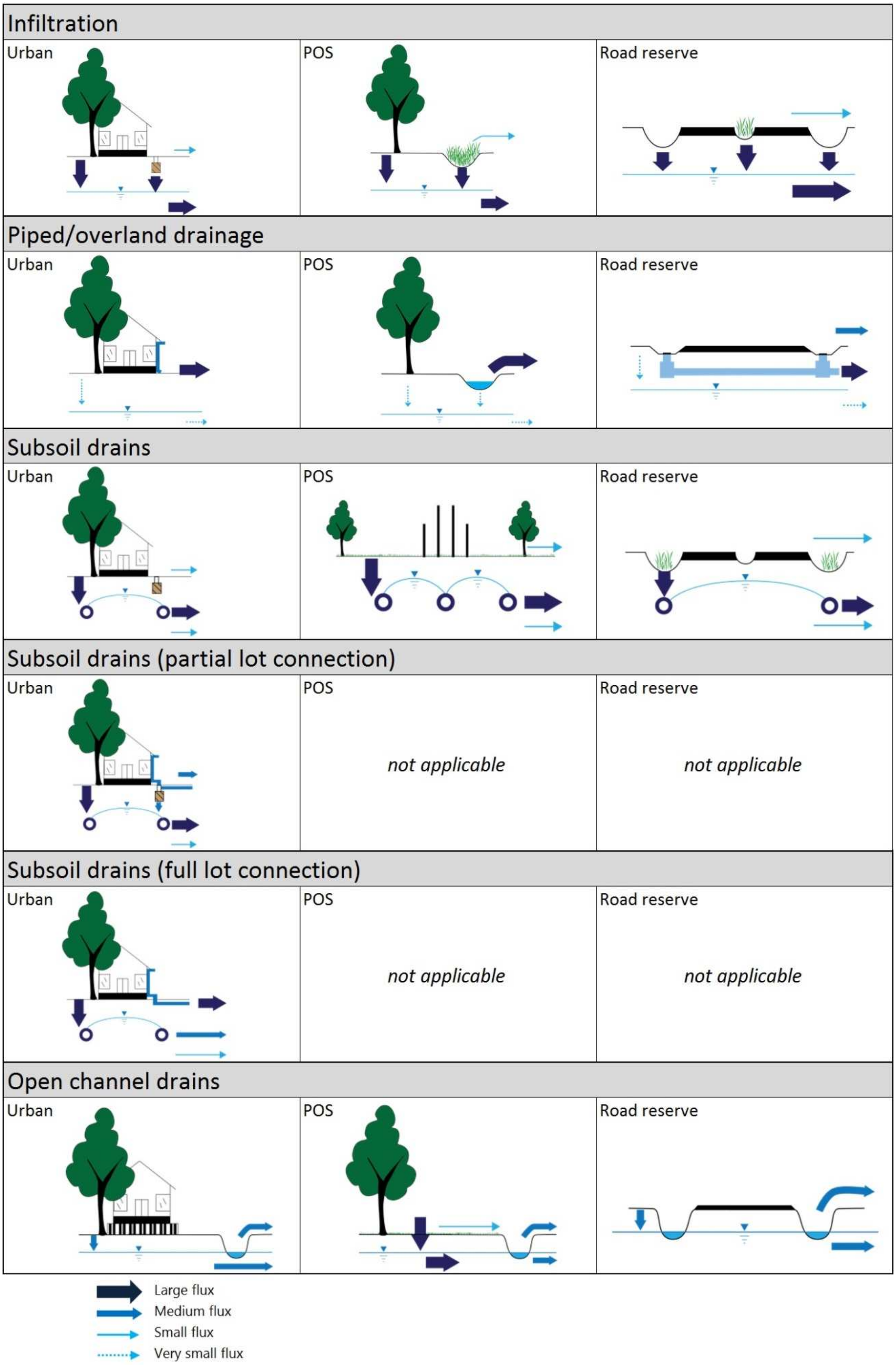


Figure 5-3: *Conceptual diagram of each drainage type in the UNDO tool*

Each subregion can only be assigned one drainage type. A typical urban development on the Swan Coastal Plain is a mixture of drainage types, and users are required to divide the development into various subregions to account for the different drainage types. A guide to subregion configuration based on drainage typology for the UNDO tool is provided in Appendix B.

Select soil type

The soil type is particularly important in the nutrient export processes on the Swan Coastal Plain of Western Australia, as a large proportion of the rainfall can infiltrate into the ground, where the water interacts with the soil matrix and groundwater and is discharged via subsoil drains or through groundwater flow to receiving water bodies. Soils are categorised according to their phosphorus retention index (PRI), porosity and vertical hydraulic conductivity. PRI is a measure of the soil's ability to retain phosphorus: soils with low iron content (such as Bassendean Sands which are common on the Swan Coastal Plain) have low to very low PRI, and soluble phosphorus concentrations leaching to groundwater systems and subsoil drains are likely to be high. The PRI assigned to each soil type will be displayed in the non-editable *Phosphorus retention index (PRI)* text box. Effective porosity and vertical hydraulic conductivity are required to calculate travel times of flow through both the unsaturated and saturated soil media. Travel times are related to the extent of potential nutrient processing. More information on PRI, travel times, nutrient processing, and soil parameters is shown in the UNDO tool technical manual, Section 5. The UNDO tool includes a map icon () located next to the drop-down menu for soil type. This map opens an interactive map which allows users to pin-point the soil type of their development. An example of the interactive map viewer is shown in Figure 5-4.

Does the subregion contain imported fill?

Imported fill is commonly used in WA soils to provide the 'Class A' foundations required to support double-brick housing and to provide adequate clearance from groundwater. It is increasingly being used to provide a matrix for phosphorus absorption. Various soil amendments are available to raise the phosphorus binding capacity of the soil. This may be important in developments on Bassendean Sands, where the soil's natural phosphorus binding capacity is very low. If the check-box is ticked, two or three text boxes will be displayed below the check box (Figure 5-5).

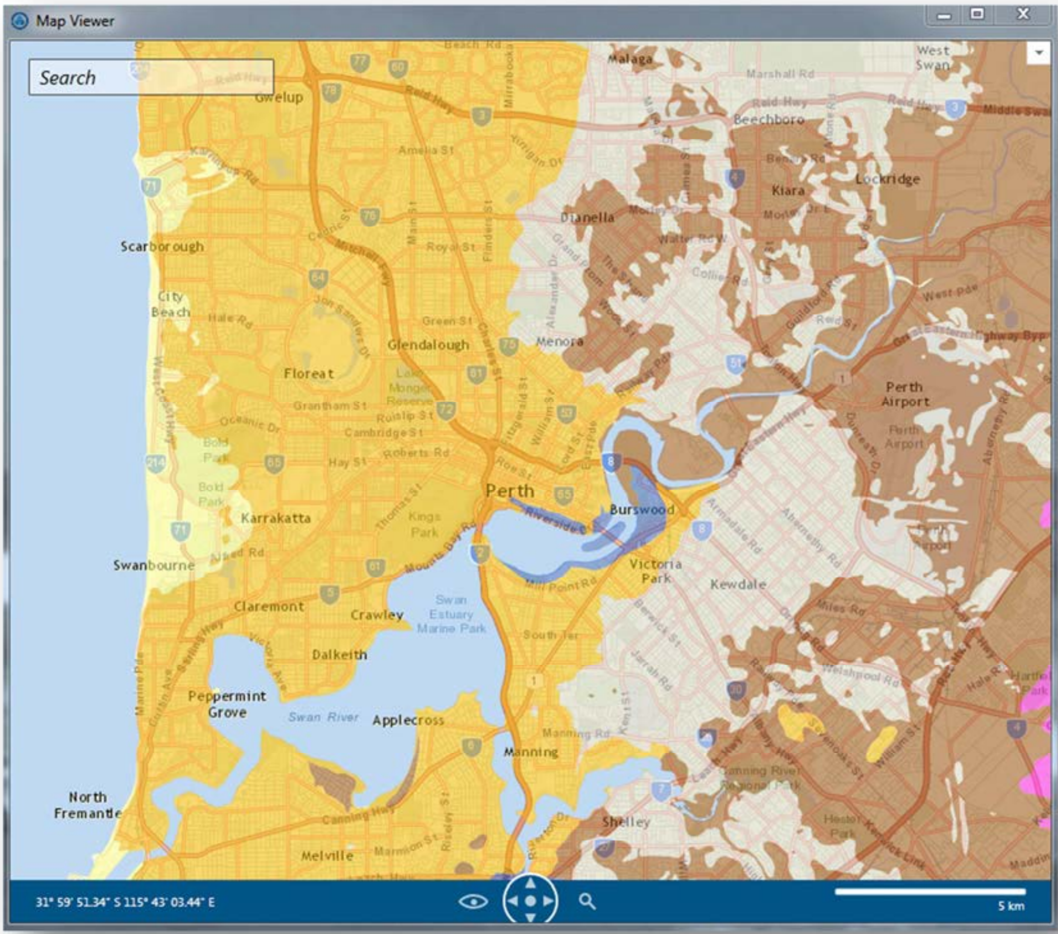


Figure 5-4: The map viewer used to help select soil type

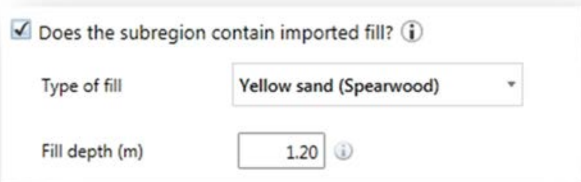


Figure 5-5: Sand fill details in the UNDO tool's export page

The first text box outlines the type of fill. At the local water management strategy stage of the project, it is unlikely that the developer will know exactly where the fill will be sourced from but this text box commits the developer to getting the fill from a certain source. There are three options:

1) **White Sands (Bassendean):** These sands have poor phosphorus binding capabilities but are often the easiest fill to source locally in developments on Bassendean Sands.

2) **Yellow Sands (Spearwood):** Spearwood sands have a much greater capacity to retain phosphorus onsite than Bassendean Sands (but not particularly good compared to iron-rich soils).

3) **Other:** This includes any other specified soils for fill not covered by the other options, and includes amended soils. If this option is selected, the user must also provide the PRI of this soil type, and attach a description of the proposed soils to the UNDO tool report.

Depth to groundwater

The depth to groundwater will characterise the distance the infiltrated water will travel through the soil profile, which will affect the amount of phosphorus adsorption onto the soil matrix. Groundwater levels are likely to fluctuate from year to year, and an **average** depth to groundwater is required for the UNDO tool.

The average depth to groundwater is expected to vary across the subregion. Ideally, subregions should have a relatively constant depth to groundwater but it is impractical to split a development into many subregions based on subtle/minor depth variations. So, subregion design is made independently of the depth to groundwater calculation (see Appendix A for a guide for subregion configuration), and the spatially average depth to groundwater is required based on each of the subregions and calculated in the pre-modelling phase (Section 2).

If a subsoil drainage system is used to control groundwater, the depth to groundwater will be equal to the depth to the subsoil drainage system (which will generally correspond to the depth of fill).

Groundwater gradient

An average groundwater gradient for each subregion is required for the UNDO tool. Users can calculate the gradient for each subregion in the pre-modelling phase using information from drilling and monitoring programs. Alternatively, groundwater gradients can be calculated using contours maps taken from any existing drainage and water management plans (if these are available for the development area).

Maps of existing groundwater levels and any proposed controlled groundwater levels are a requirement of a local water management strategy under the *Better urban water management* framework (WAPC 2008), so the information on groundwater gradient and depth should be readily available for the UNDO tool at the appropriate stage of development.

Subregion contains onsite sewage disposal system

Onsite sewage disposal systems can be a significant source of nutrients in urban or rural living areas. Although it is a general requirement that future residential developments are connected to mains sewerage, exceptions are allowed under certain circumstances, and users should refer to the *State sewerage policy* (Department of Health 2011) to ensure that any use of onsite sewage disposal systems in a development is aligned with this policy. Developments in rural areas and urban fringe locations are examples where onsite sewage disposal systems may be installed due to absence of sewerage infrastructure and provision under the *State sewerage policy*. If onsite sewage disposal systems are used in the UNDO tool, the *'subregion contains onsite sewage disposal system'* tick-box must be selected, and two text boxes will appear (Figure 5-5). The top text box is a drop-down list of the type of septic installed – two types are available in UNDO: Septic tanks and alternative treatment units (ATUs).

Figure 5-6: *Onsite sewage disposal system details in the UNDO tool*

Septic tank systems generally consist of one or two watertight cylindrical tanks and one or two sets of drainage receptacles with holes in their sides and no base, e.g. leach drains or soakwells. When wastewater passes through the septic tanks, heavier solids sink to the bottom and undergo bacterial digestion. This reduces the mass of solids and changes its composition to sludge which builds up in the bottom of the tank. Materials such as grease and oil float to the surface in the tanks to form a crust over the liquid. The remaining liquid, called effluent, flows from the tanks into the drainage receptacles to soak into the surrounding soil. Since 1989, most household septic tank systems have been installed with either two leach drains or two sets of soakwells. These systems are called alternating systems as they have a diverter box that can change the flow of effluent allowing one half of the soakwells or one of the leach drains to be shut off at any time.

Alternative treatment units (ATUs) are local wastewater systems which can be used instead of septic tanks. In some locations they are used to treat effluent from more than one house. ATUs have advanced physical, biological and/or chemical treatment systems that can reduce coliform, nitrogen, phosphorus and suspended solid effluent concentrations. Aerobic treatment units treat wastewater under aerobic conditions and can have a series of additional treatment components before discharging the treated wastewater.

For an ATU to be accredited for use in Western Australia, the system must have its performance independently verified and reported to the Western Australian Department of Health. These performance tests measure the reduction rates of total coliforms, suspended solids, nitrate, ammonium, total nitrogen, soluble phosphorus, total phosphorus and biological oxygen demand. ATUs have regular service requirements (usually quarterly) and maintenance must be through an authorised person or their staff/contractors. Users of the UNDO tool should refer to the *Code of practice for the design, manufacture, installation and operation of Aerobic Treatment Units* (Department of Health 2001) if the proposed development may use ATUs and users require more information. Further information is available online at http://www.public.health.wa.gov.au/3/663/2/aerobic_treatment_units.pm.

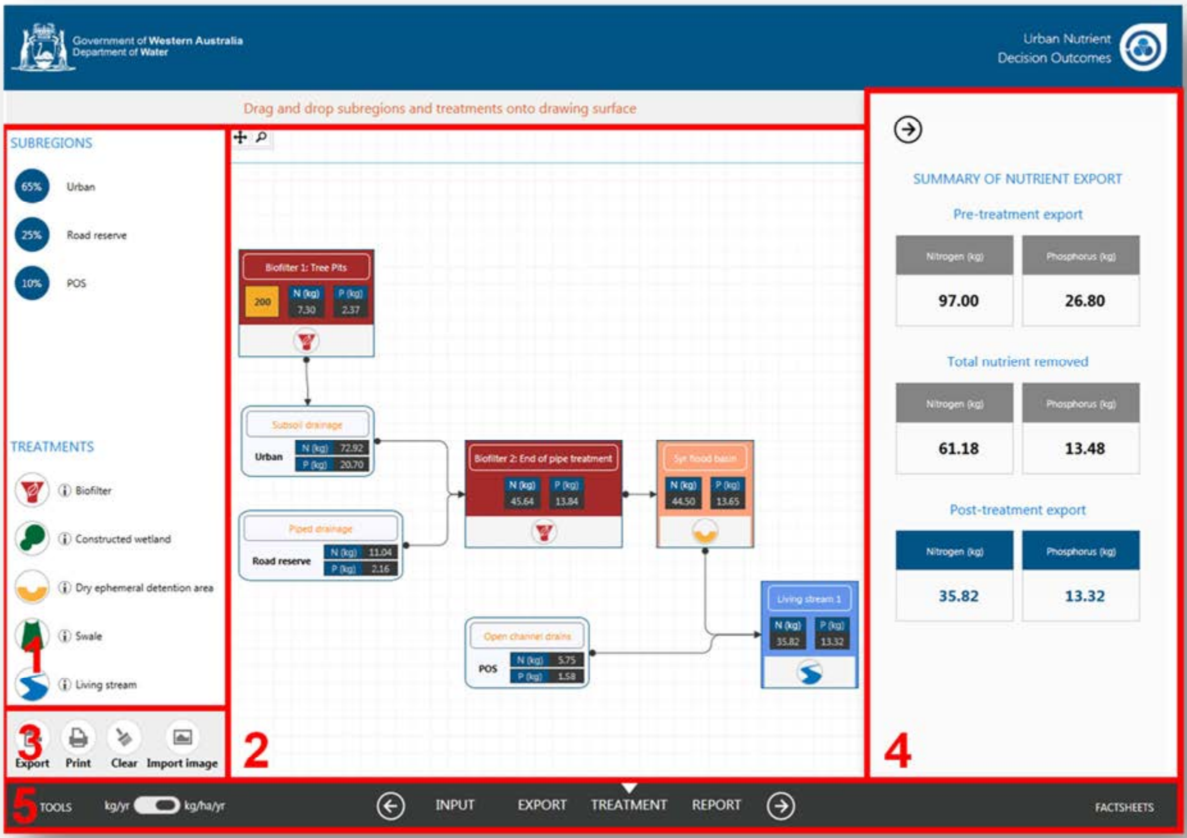
More information on onsite sewage disposal systems can be found in the UNDO tool technical manual, Appendix E.

5.2 Indicative average nutrient concentrations

The UNDO tool calculates an indicative nutrient concentration as part of the nutrient export algorithms. Details of the calculations are shown in the Section 4 UNDO tool technical manual. The calculations assume an annual rainfall of 750 mm, and do not take into account the inter-annual variability of flow or nutrient fluxes. The values are a guide only to show users that the UNDO tool is predicting realistic outputs. It should also be noted that the concentration is not directly proportional to the export load, as drainage systems that export more flow (e.g. piped drainage systems) can export an equivalent catchment load for much lower nutrient concentrations.

6 Page 3 – Treatment

The third page of the UNDO tool is the *treatment* page, which allows users to input structural treatments, and calculates the amount of nutrient removed by these engineering structures. Users can size the structures, link them to appropriate subregions and create a 'treatment train' of structural treatments if desired. The configuration of the export page is shown in Figure 6-1.



1: Subregion and available treatment list

2: Treatment canvas

3: Treatment tools

4: Summary export loads and reductions

5: Navigation ribbon

Figure 6-1: *Configuration of the UNDO tool treatment page*

6.1 Structural treatments available in the UNDO tool

The following structural treatments are available in the UNDO tool:

- Biofilters (also referred to as bioretention systems)
- Constructed wetlands
- Swales
- Living streams
- Infiltration/detention basins
- Floating treatment wetlands
- Spiral-wrapped media filters

This section describes the methodology for entering treatments into the UNDO tool and the definition of each treatment (including its best practice design):

Biofilters

Biofilters (also known as biofiltration systems, bioretention systems and rain gardens) are excavated basins or trenches filled with porous filter media and planted with vegetation to remove pollutants from stormwater runoff. They remove nutrients from drainage waters by chemical adsorption, plant uptake and microbial assimilation.

Factors that should be considered in the design of biofilters include:

- their integration into the development's landscape design
- location as part of planning and design of roads and lots
- vegetation appropriate to the climate and desired pollutant removal
- the impacts of potential acid sulfate soils on filter media and/or structures where relevant.

The Ballee Road biofilter in Busselton is shown in Figure 6-2. For the purposes of UNDO, biofilters **must** have the following design attributes, with exceptions where noted:

- **Substrate** (Payne et al. 2015): Should consist of a stone/mulch layer, a filter layer, and a transition layer. The stone layer should be > 50 mm deep and have no fines. The filter layer should be at least 300 mm deep, and have a hydraulic conductivity in the range of 100–300 mm/hr. This includes clay and silt (< 3%), very fine sand (5–30%), fine sand (10–30%), medium to coarse sand (40–60%), coarse sand (7–10%) and fine gravel (< 3%). The pH should be 5.5–7.5 with at least 3% of low nutrient-content organic matter (< 80 mg/kg orthophosphate, < 1000 mg/kg nitrogen). The soil should be amended with 5% mulch and 5% hardwood chips by volume (optional based on location and depth to groundwater). The transition layer should be at least 100 mm deep, and should be clean, well graded sand with < 2% fines.

- **Plants:** At least 50% of the plants should be effective at nutrient removal. The remainder should be local, native, ephemeral plants. There should be 8–12 plants per m^2, depending on species. Plants require irrigation in summer months for biofilters to be effective. More information on effective plant species can be found in the *Adoption guidelines for stormwater biofilter systems* (Payne et al 2015).

Figure 6-2: *Ballee Road biofilter in Busselton*

Biofilters can be unlined or have a lined submerged zone. More information on appropriate biofilter design can be found at:

Payne, E., Hatt, B., Deletic, A., Dobbie, M., McCarthy, D. and Chandrasena, G. 2015, *Adoption guidelines for stormwater biofilter systems,* CRC for Water Sensitive Cities, Melbourne, Australia.

Deletic A, McCarthy D, Chandrasena G, Li Y, Hatt, B, Payne E, Zhang K, Henry R, Kolotelo P, Randjelovic A, Meng Z, Glaister, B, Pham T, Ellerton J. 2014, *Biofilters and wetlands for stormwater treatment and harvesting,* Cooperative Research Centre for Water Sensitive Cities, Monash University, October 2014.

FAWB 2009, *Adoption guidelines for stormwater biofiltration systems,* Facility for Advancing Water Biofiltration, Monash University, June 2009.

Monash University 2014, *Vegetation guidelines for stormwater biofilters in the south-west of Western Australia*, Monash University, Water for Liveable Cities, Victoria, Australia.

Constructed wetlands

Constructed wetlands are extensively vegetated water bodies that use sedimentation, filtration and biological uptake processes to remove pollutants from stormwater. Significant land areas are usually required to accommodate large detention volumes (generally 1 to 2% of the total catchment area).

Typically, a constructed wetland will include the following design features:

- an inlet gross pollutant trap
- a high flow bypass drain
- inlet zone for energy dissipation and sediment removal
- flow spreaders (porous rock weir) to vegetation bands across shallow wetland to maximise contact of vegetation with flows and promote sedimentation
- a deeper open water body with a submerged vegetation zone, and orifice outlet device to provide controlled release of flow and ensure adequate detention time.

These design features are shown in Figure 6-3 (taken from DoW 2007).

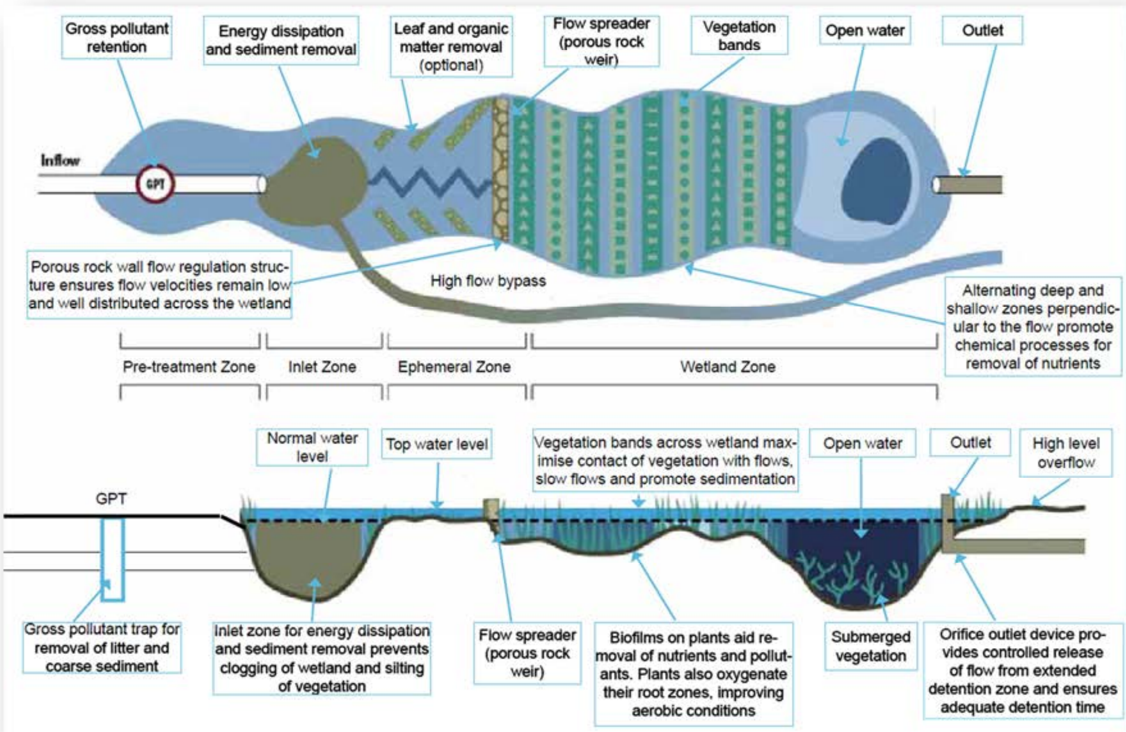


Figure 6-3: *Typical schematic plan for a constructed wetland*

Constructed wetlands should be separated from groundwater and only constructed in suitable soil conditions. Mosquitoes, midges and acid sulfate soils need to be managed in the design and hydrodynamic conditions should be considered in the design process.

More information on the design and construction of constructed wetlands can be found at:

Department of Water 2004–07*, '*Section 5.2 of Chapter 9 – Structural controls'*, Stormwater management manual for Western Australia, 2004-07, Department of Water, available at http://www.water.wa.gov.au/.*

Engineers Australia 2006*, Australian runoff quality: a guide to water sensitive urban design, 2006, Engineers Australia, available at http://www.arq.org.au.*

Melbourne Water 2005*, Constructed wetland systems – design guidelines for developers, 3005, Melbourne Water, Victoria.*

Wong, THF, Breen, PF, Somes, NLG & Lloyd, SD 1999*, Managing urban water using constructed wetlands, CRC for Catchment Hydrology, Industry report 98/7.*

Swales

Swales are grassed or vegetated (typically with Western Australian native plants) broad, shallow channels used to collect and convey stormwater flows, promote infiltration, reduce stormwater peak flow rates and discharge volumes, and remove sediments and nutrients. Swales use a combination of physical and biochemical processes to treat stormwater.

Swales should incorporate the following design factors:

- A longitudinal slope should be selected to avoid scouring, to protect public safety and to prevent excessive periods of stagnant water.
- Vegetation type should be selected considering height and cover, the ability to convey expected flows, aesthetics, pollutant removal and driver visibility (when used in road reserves).
- They should be integrated into landscape design, and their location should be considered with regard to underground services.

An example of a vegetated roadside swale from the City of Subiaco is shown in Figure 6-4.

Swales differ from biofilters in WA in that they do not have strict soil media design constraints or strict plant species constraints. This may make them cheaper than biofilters but they do not treat nutrients (particularly phosphorus) as efficiently as biofilters. More information on the design of swales can be found in the following documents:

Department of Water 2004–07*, '*Section 4.1 of Chapter 9 – Structural controls'*, Stormwater management manual for Western Australia, 2004-07, Department of Water, available at http://www.water.wa.gov.au.*

Engineers Australia 2006*, Australian runoff quality: a guide to water sensitive urban design, 2006, Engineers Australia, available at http://www.arq.org.au/.*

Figure 6-4: *Vegetated swale in the City of Subiaco*

Living streams

A living stream is a constructed or retrofitted stormwater conveyance channel that mimics the characteristics (morphology and vegetation) of a natural stream. As well as conveying stormwater, they treat it using physical and biological processes and create diverse habitats for wildlife. They can become complex ecosystems that support a wide range of plants and animals.

Some factors to consider in the design of living streams include:

- They should be integrated with the landscape design of the public open space.
- The terrain (particularly the slope) and the geology of the landscape should be considered.
- They should not intersect the dry season watertable.

A typical cross-section of a living stream is shown in Figure 6-5 (note that active public open space such as playgrounds, parks and ovals can be integrated in the 5–100 year bank level in a living stream design; this is not demonstrated in Figure 6-5).

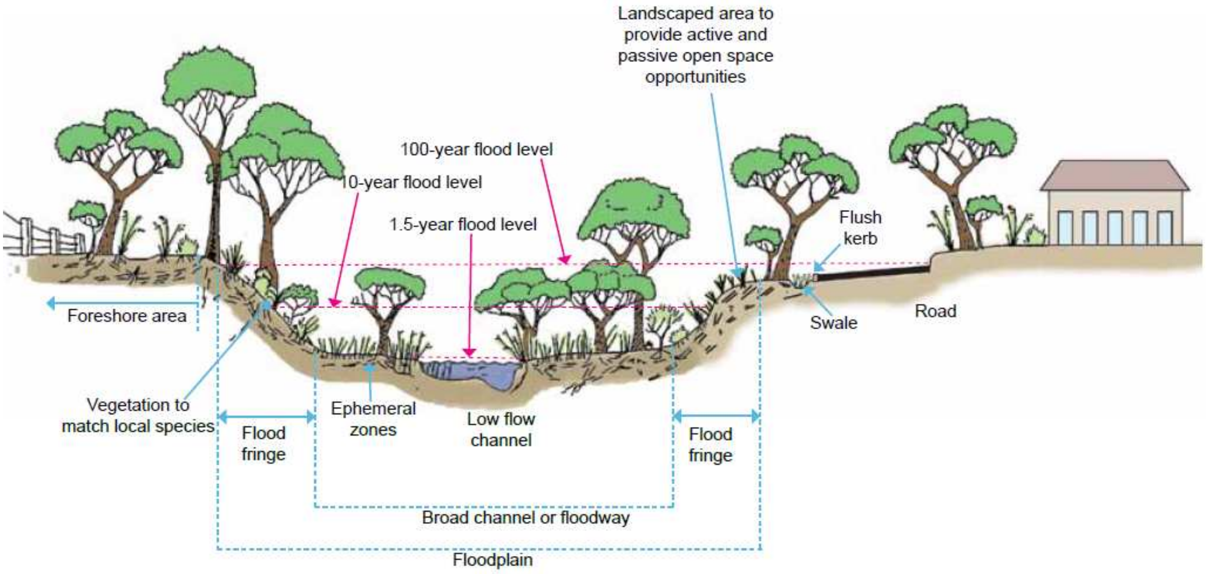


Figure 6-5: *Typical cross-section of a living stream*

More information on the design of living streams can be found in the following documents:

Department of Water 2004–07, 'Section 4.3 of Chapter 9 – Structural controls', *Stormwater management manual for Western Australia, 2004-07, Department of Water, available at http://www.water.wa.gov.au.*

Engineers Australia 2006, *Australian runoff quality: a guide to water sensitive urban design, 2006, Engineers Australia, available at http://www.arq.org.au/.*

Infiltration/detention basins

Nutrient processing in the UNDO tool is similar for infiltration systems and dry/ephemeral detention areas so they are lumped into a single treatment option.

Dry/ephemeral detention basins are landscaped areas formed by simple dam walls, by excavation below ground level or by using or enhancing natural swales or depressions. These areas primarily serve to capture and store stormwater to prevent excessive runoff and channel erosion in receiving environments, and as areas to remove particulate-based contaminants and sediment. Infiltration basins are depressions designed to capture stormwater before infiltration into the soil profile. They are effective on sandy soils, simple to construct and can be constructed as linear trenches in confined areas.

Both infiltration systems and dry/ephemeral detention areas have a base level at or above the long-term maximum regional groundwater level, with the area inundated as a result of intermittent stormwater inundation rather than as a result of groundwater exposure.

Infiltration systems and dry/ephemeral detention areas are often multiple-use, with these areas used for recreation during dry periods and for stormwater detention or infiltration during periods of rainfall (figure 6-6). They need to be designed for mosquito breeding prevention so that no water will pond after 96 hours.

Figure 6-6: *A typical infiltration/detention basin on the Swan Coastal Plain*

More information on the design of infiltration systems and dry/ephemeral detention basins can be found in the documents:

Department of Water 2004–07, 'Sections 3.1 and 5.1 of Chapter 9 – Structural controls', *Stormwater management manual for Western Australia, 2004-07, Department of Water, available at http://www.water.wa.gov.au.*

Floating treatment wetlands

Floating treatment wetlands consists of a buoyant media that is planted with vegetation (such as rushes and sedges) and are used to improve the water quality of open water areas, such as lakes, compensation basins and rivers. Plant roots are encouraged to grow within the water column, taking up nutrients within the water, entrain sediments and provide a surface for biofilm growth. Surface vegetation requires periodic harvesting, removing accumulated nutrients in the process.

Floating treatment wetlands are a commercially available product. Manufacturers may provide site specific design and operation recommendations. The following are general recommendations for most floating treatment wetland applications:

- Floating treatment wetlands are recommended to cover 50% of open water areas.

- The placement of floating treatment wetlands should be such to minimise stormwater shortcutting and maximise exposure time.
- Floating treatment wetlands should ideally be placed in permanent water bodies or have a maintenance regime tailored to ephemeral conditions.
- Periodic maintenance is required, which may include vegetation harvesting, replanting and floating wetland placement.

Figure 6-7: *Floating treatment wetlands, photo courtesy of SPEL environmental.*

Spiral wrapped media filters

Spiral wrapped media filters (SWM filters) are a stormwater treatment that physically and chemically removes nutrients from stormwater. Filters can consist of wrapped, porous geotextile material. Spiral wrapped media filters are used in conjunction with gross pollutant trap pre-treatment and baffled stormwater detention. Filters are considered to be a tertiary level treatment and should be accompanied by pre-treatment to minimise high sediment loads and gross pollutants reaching the filter tanks.

A regular maintenance regime is recommended to maintain optimal performance. This would typically include a 6 month inspection and education of any accumulated sediment on the base of the tank. Replacement of the filters is recommended only when hydraulic conductivity reaches the stage where water can no longer pass through the filters (typically >5 years).

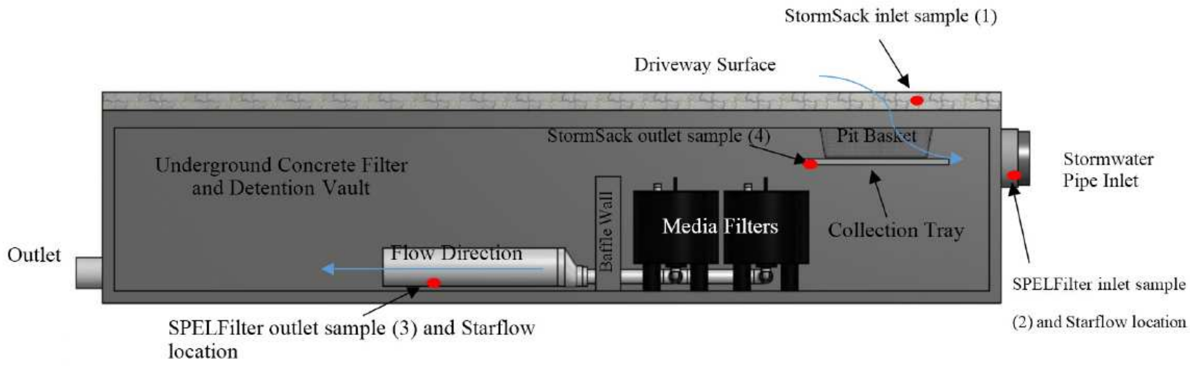


***Figure 6-8**: Schematic of spiral wrapped media filter installation (Drapper & Hornebuckle 2015).*

6.2 Using the treatment canvas

The treatment canvas allows for quick and easy assessment of a variety of nutrient treatment configurations. Structural treatments are entered by dragging the relevant subregion and the desired treatment from the ‘subregion and treatment list’, and dropping onto the ‘treatment canvas’ (Figure 6-1). Users can then connect the subregion to the treatment by clicking inside the subregion icon, and dragging the connector to the centre of the treatment icon. The UNDO tool allows a ‘treatment train’ approach to implementing structural treatments. This means that water and nutrients exported from a subregion can flow through a series of treatments, with each treatment removing a proportion of nutrients as the water passes through. Other subregions can connect to either the beginning of the treatment train, or to any point within the train.

Two basic methods are used in the UNDO user interface to represent treatments:

- embedded treatments
- sequential treatments.

Figure 6-9 shows an example of a treatment train that includes two embedded treatment types (a biofilter which receives impervious runoff from 200 lots, and a dry ephemeral detention area that the piped drainage overflows to) and two sequential treatments which form a treatment train (and end-of-pipe biofilter flowing to a living stream).

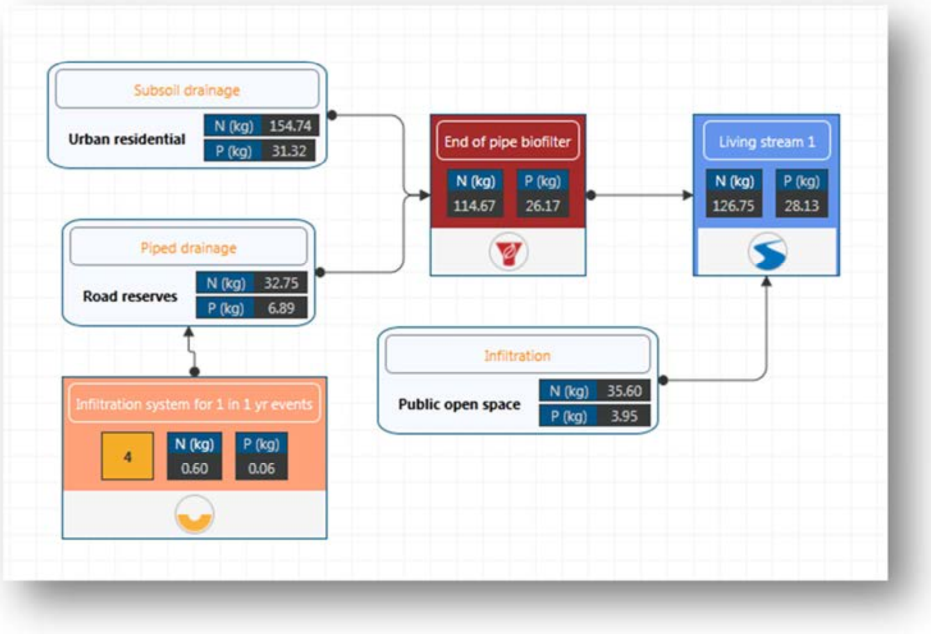


Figure 6-9: *Nutrient treatment canvas with a configured treatment train for the UNDO tool*

Embedded treatments

Embedded treatments are spread throughout a subregion, and treat a fraction of the subregion. For example, tree-pits can be represented by small bioretention systems (provided they have adequate substrate) that treat impervious runoff from a road or carpark section. In some cases there may be many of these identical treatments in a subregion. Rather than creating a new subregion for each tree-pit, the UNDO tool allows for users to *embed* these treatments and create many replicas of this treatment within a subregion.

To enter an embedded treatment, from the treatment canvas users simply connect the treatment icon to the subregion icon in that order. Embedded treatments have an orange number box displayed to their right showing the number of replicates of this treatment within the subarea, which differentiates them from *sequential* treatments. They also are displayed with the name of the treatment on the top of the icon, the mass of nitrogen and phosphorus removed (in kg) and a symbol at the bottom of the icon to represent the type of embedded treatment (Figure 6-10a).

To configure a treatment (embedded or sequential), the user double-clicks the treatment icon. The configuration of an embedded treatment is shown in Figure 6-10b.

Figure 6-10: *a) Embedded treatment icon, and b) configuration of embedded treatment in UNDO*

The user is required edit five text boxes in the treatment configuration:

1. **Name:** This is the name given to a certain type of treatment. They will be defaulted to Biofilter 1, Biofilter 2, etc., though the user may want to be more explicit about naming treatments (e.g. Liege St rain garden) which may be useful when describing the UNDO tool development in the local water management strategy document.

2. **Treatment size (m^2):** This refers to the surface area of the treatment. The UNDO tool makes some assumptions about the remaining dimensions of the treatment so the area is the treatment's only design aspect that the user must enter (for more information see the UNDO tool technical manual).

3. **Treated size (ha):** This is the total area that drains to the nutrient treatment from a particular subregion. This is irrespective of whether it treats only the impervious area or all flow sources. For example, if a residential block discharges to a biofilter *but only the impervious area is treated by the biofilter*, the entire area of the block needs to be entered into this section. The treatment module of the UNDO tool decides the split between impervious/subsoil and deep groundwater flow.

4. **No. of replicates:** This refers to the number of identical treatments (same treatment size, drainage type and treated area) in the subregion.

5. **Inflow source(s):** This will only appear for in-line treatments (biofilters, spiral-wrapped media filters, swales, and detention/infiltration basins) and refers to the component of the drainage that enters the treatment (runoff only, subsoil drainage, etc.). Four options are available from a drop-down menu. These are described in detail in the following section.

The embedded treatment icon will show the total amount of nitrogen and phosphorus (in kg) removed from the sum of the embedded treatments. The treated size multiplied by the number of replicates must be smaller than or equal to the size of the subregion. There may be more than one type of embedded treatment in a subregion (e.g. a subregion can have embedded swales and embedded biofilters).

Sequential treatments

Sequential treatments differ from embedded treatments in that the entire subregion will discharge to the treatment, and only one sequential treatment will be allowed per subregion. Sequential treatments can be connected to form a 'treatment-train' where two or more sequential treatments are joined. An example of a treatment train is shown in Figure 6-1 where the 'end-of-pipe treatment' biofilter flows to a living stream. Multiple subregions can discharge to a single sequential treatment, and additional subregions can connect to any treatment on a treatment train (e.g. in Figure 6-1 the public open space discharges to the living stream only).

If sequential treatments are used in UNDO, subregions must be configured so that the entire subregion will flow to the sequential treatment. This is outlined in detail in *Appendix A: A guide to configuring subregions in the UNDO tool*.

Inflow sources

UNDO treatments are broadly divided into two categories, 1) end-of-pipe treatments and 2) in-line treatments. End of pipe treatments generally treat all of the water that is delivered from a subregion, and includes Constructed Wetlands, Floating Treatment Wetlands and Living Streams. The remaining treatments (biofilters, detention/infiltration basins, swales, and spiral wrapped media filters) are classed as in-line treatments. Inline treatments generally do not treat groundwater, and rely on inflow from pipes (stormwater or subsoil pipes) or from overland runoff.

The source of the flow for in-line treatments will affect how much of the total nutrient from the upstream catchment that it will

Structural treatments can be designed to receive inflows from either impervious runoff or a combination of impervious runoff, subsoil drainage and groundwater drainage. To allow for different inflow treatment configurations in the UNDO tool, structural treatments have the option to treat various components of the flow. These include:

- **Sandy soils – Runoff only (infiltration on lots):** This option is selected when the treatment system receives inflows from impervious runoff only, *and* all house lots that are connected to the treatment infiltrate the first 15mm of rainfall on site. The treatment efficiency is relatively low (see figure 6-1) for these systems, as a large proportion of the total flow is bypassed – it infiltrates to the groundwater and is not treated by the structure (however, treatment can occur via the soils more efficiently in these systems where the soils have a medium to high PRI value). This option is also selected if the BMP treats runoff only in sandy catchment on POS or parkland. When using this treatment type with embedded treatments, it is important that the treated area entered includes the entire catchment of the treatment, as opposed to the impervious area only.

- **Sandy soils – Runoff only (full lot connection):** This option is selected when the treatment system receives inflows from impervious runoff only, *and* all house lots that are connected to the treatment are fully connected to the stormwater system. The treatment efficiency for these systems is medium, as more of the water is routed through the structure (however, there is not the opportunity of this water to be treated by the soils matrix, which occurs in infiltration on lot systems) – however some water is still bypassed – for example the pervious areas of the catchment – as the majority of the rainfall will infiltrate to the groundwater in these areas and will not be treated by the BMP. This option is also selected if the BMP treats road runoff only, and the road reserve has a pit-and-pipe system. When using this treatment type with embedded treatments, it is important that the treated area entered includes the entire catchment of the treatment, not just the impervious area).
- **Sandy soils – runoff and subsoil drainage:** This solution is only available for subregions that use subsoil drains. The subsoil drains can be connected directly to the BMP as an inflow, or (more commonly) the subsoil drainage system is connected to a pit-and-pipe stormwater system which will discharge to these BMPs. The treatment efficiency for these systems is medium, as more of the water is routed through the structure – as a large proportion of the water that infiltrated and is picked up by subsoil drains is re-routed to these treatment (in these situations there is the opportunity of this water to be treated by the soil matrix, and again by the structural treatment) – however some water is still bypassed which flows in the regional groundwater system and is not picked up by the subsoil drains. In-line treatment systems are not designed to treat regional groundwater, so this option is not available.
- **Heavy soils – runoff:** This option is for heavy (i.e. clays or clayey loam) soils that incorporate a piped or surface water drainage stormwater system. The soils have limited infiltration capacity, and almost all of the runoff is routed to the BMP. Therefore they have a very high treatment efficiency. This is similar to the hydrological conceptualisation used in MUSIC (eWater 2012), and the amount of treatment will be identical to that in a standard MUSIC model (with parameters taken from the UNDO tool technical guide).

A summary of the drainage components available to each of the structural treatments in the UNDO tool is shown in Figure 6-11.

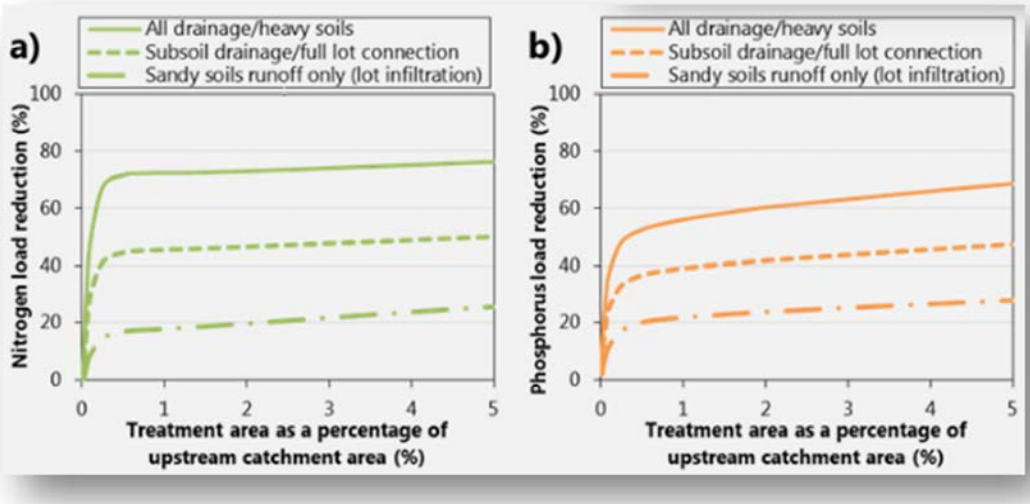
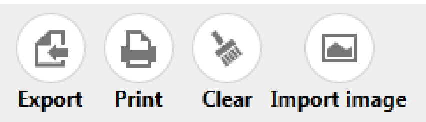


Figure 6-11: *Efficiencies of various inflow sources of drainage for inline treatments in the UNDO tool*

Treatment tools

The four treatment tools are located above the UNDO tool ribbon at the bottom left of the treatment page.



1) **Export:** gives the user an option to export the treatment canvas as a figure (.png).

2) **Print:** provides the user with the option to send the treatment canvas to the printer.

3) **Clear:** will clear the treatment canvas. This includes all treatments, subregions and background image.

4) **Import image:** allows the user to import a background image. Images are automatically compressed to avoid performance issues in UNDO. Users can set the transparency of the image once it is imported.

7 Page 4 - Reporting

The UNDO tool reports are automatically generated using the report module on the tool's ribbon. A report is generated each time the user navigates to this panel. When the user is satisfied with the development design, the UNDO tool report can be printed and submitted (generally as an Appendix to their local water management strategy).

Checklist for submitting a report

UNDO tool reports are not useful to decision-making authorities by themselves – they require extra information relating to the development design. It is recommended that the following information is submitted with an UNDO tool report (many of these items, particularly the development maps and groundwater maps, will already be included as part of the greater local water management strategy document):

1) **Development maps.** The development maps associated with UNDO should clearly show the following (multiple maps may be required to display these items effectively):

    a. The breakdown of the development into subregions

    b. The breakdown of the development into land-use categories (this includes landscaping of the development's public open space and road reserves (with respect the UNDO tool's land-use categories)

    c. The drainage system, clearly defining the overland flow drainage and subsoil drainage system (if it is present)

    d. The position of each of the structural BMPs and their corresponding catchment areas

2) **Groundwater maps.** These should show groundwater contours used to derive the groundwater slope and the depth to groundwater.

3) **Laboratory reports:** These are required if imported fill is used, and are required to test the PRI of the fill.

In addition, UNDO tool files (.undo) may be requested in some instances. If targets for the development area are stipulated by local or state government agencies, proponents should also compare the results of the development to target nutrient export rates.

8 Updates and version control

It is acknowledged that there are significant gaps for much of the data relating to urban nutrients in Western Australia. It is important that the design of the UNDO tool incorporates the flexibility to easily update and build in new or updated information. It is also important that there is a clear and transparent version control process that accompanies the transfer of new information and data to updates of the UNDO tool.

The process to make new data available to the UNDO tool is shown in Figure 7-1. Information submitted to the UNDO team could relate to any part of the UNDO tool, and may include (but not be limited to) the following examples:

- Updated input rates for land-uses based on better survey results or more recent literature
- The implementation of new structural treatments
- Updated treatment curves for existing structural treatments based on laboratory or site data or modelling
- The inclusion of different soil types or updating the parameters of the soil types
- New or advanced onsite sewerage disposal systems
- Updated parameters for nutrient uptake from soils
- Updated process algorithms for water and/or nutrient movement and uptake through the soils and/or groundwater
- Other innovative nutrient reduction systems or processes

Information can be submitted by any user of the UNDO tool or proponent with an interest in the tool. This may include universities, private consultants, industry bodies or state / local government.

When information is submitted, the UNDO tool team from the Department of Water will require a published report or peer reviewed journal paper, with links to raw data so the claims can be referenced and queried by the report's author(s). For example, if a new structural treatment is promoted for the UNDO tool by a company that manufactures this treatment, it will not be sufficient to supply a brochure with removal rate summary for this treatment; a published scientific study (in the form of a journal paper or a published report) will be required for assessment by the UNDO tool team.

If the new information is deemed potentially suitable by the UNDO tool team, it will be distributed to the UNDO tool technical advisory group (TAG) for comment, which will include how the information will be used in the UNDO tool, and how the tool will change (based on the results of standardised test catchments). The TAG consists of members of the private industry (the Urban Development Institute of Australia's Water Committee of Western Australia), local government, state government and universities. The TAG will have an opportunity to respond to the changes, and more information may be sought, or the new information may be over-ruled by the TAG and the deemed unsuitable for the tool (if the majority of the TAG agrees). If the information (and the proposed use of the information in the tool) is deemed suitable by the TAG, the UNDO tool team will update the relevant documentation, and inform the email list of the change to the next version of UNDO tool. Users will have the opportunity to save their developments and the required information before the new version of the tool is launched.

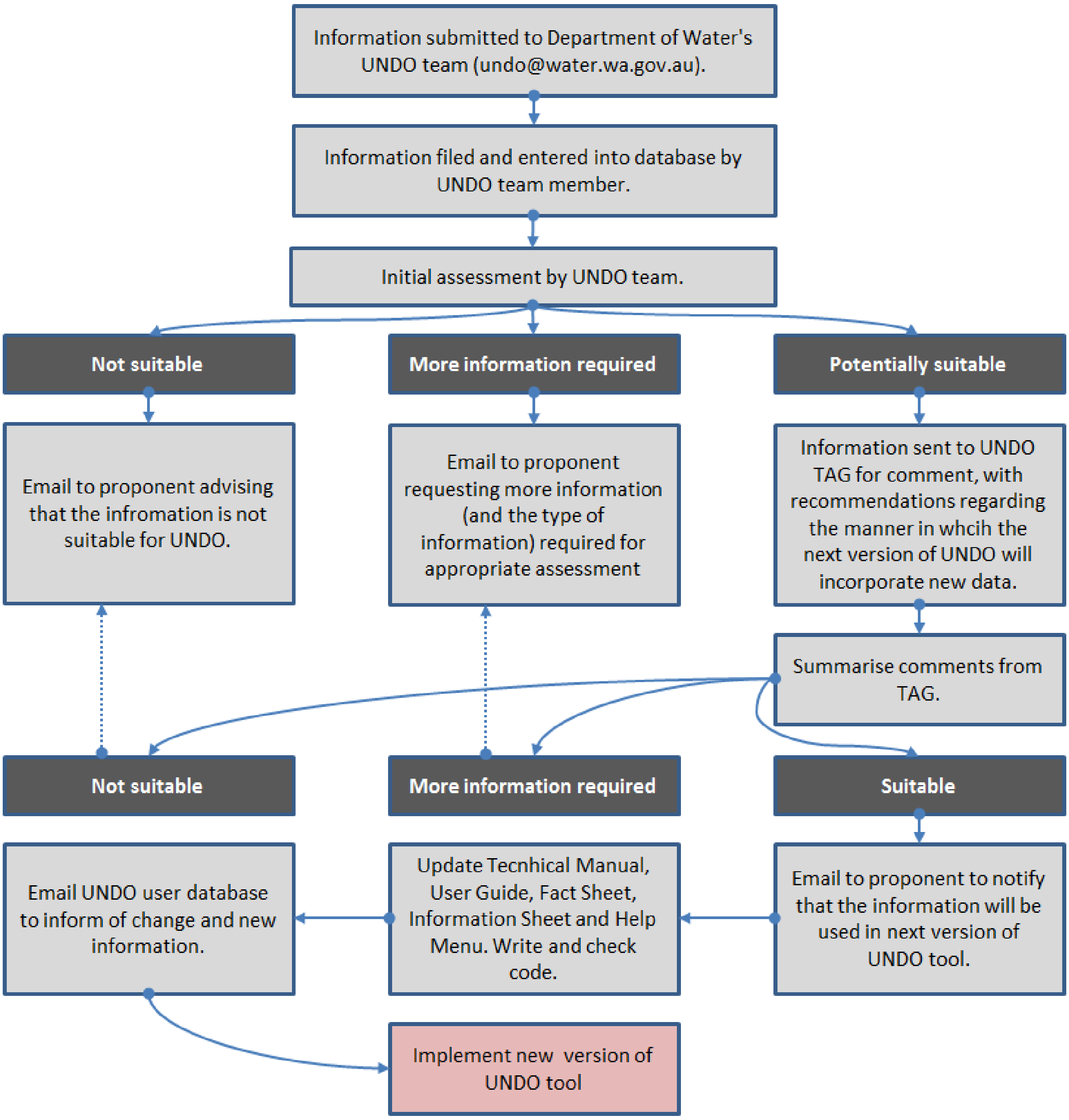


Figure 7-1: *Version update process for the UNDO tool*

Appendix A: A guide to configuring subregions in the UNDO tool

The basic building blocks of the UNDO tool are called *Subregions*. The sum of all subregions in an UNDO project will be equivalent to the total development area. A subregion is simply a portion of land within the development area – subregions can represent a mixture of land categories (e.g. public open space, road reserve and urban residential) or they can represent a single land category. There is no limit to the number or size of subregions that can be entered into an UNDO project.

Some recommended basic rules and guidance for dividing a development into subregions for an UNDO project:

Rule 1: Minimise the number of subregions.

A development may be represented by a single subregion but most UNDO projects will require multiple subregions. There is no limit to the number that a user can enter into the UNDO tool but a maximum of around 12 subregions is recommended. The tool becomes cumbersome using more than this: UNDO projects are simpler to handle and the computation time is fastest and reporting and assessment simpler when the smallest possible number of subregions is used. That is, the principle of parsimony is recommended when dividing an UNDO project into subregions –start with as simple a solution as possible and gradually build in complexity. The following rules provide appropriate guidance for dividing a development into subregions.

Rule 2: Divide subregions based on drainage and soil type.

Each subregion is required to have the same drainage type and soil type (including fill properties). If a development, or part of a development, has different drainage and or soil characteristics, the UNDO tool requires that the user splits the development into multiple subregions. This is very common; for example, if a development uses subsoil drains to control groundwater levels then this is the pathway for urban lots. However, if a traditional pit-and-pipe system without any infiltration systems is used to manage road runoff, the urban residential land and the road reserves will need to be split into two subregions. A detailed guide for dividing subregions based on drainage type in the UNDO tool is provided in Appendix B. Note that when splitting a development into multiple subregions based on soil and drainage type, users must always consider the 5% principle – this is explained in Rule 3.

Rule 3: Use the 5% principle.

In considering the drainage and soil type, it is impractical to be overly precise when dividing a development area into subregions. For example, a change in soil type may occur on a very small portion of a proposed subarea, or a small structural treatment in an urban development may not be controlled by subsoil drainage in the manner of the remainder of the development. While, according to Rule 2, this would require an extra subregion, building subregions with a very high level of precision can quickly lead to overly complex and cumbersome UNDO projects. For the sake of simplicity, it is recommended that a 5% principle, as stated below, is followed:

> *If the drainage type or soil type in a portion of a subregion is different to the remainder of the subregion but constitutes 5% or less of the subregion's total area, this difference should be ignored, and the anomalous portion be considered to be part of the larger subregion.*

This principle makes using UNDO much simpler. For example, a development may have many small biofilters used to treat impervious flow. Biofilters will generally have a different drainage and soil type to the residential or road reserve portion of the development. However, the sum of all of these biofilters may equate to only 2% of the subregion's area. Rather than create a separate subregion to represent the portions of land used to input each of these biofilters, the 5% principle allows users to lump the biofilters with the urban residential subregion. So there will only be one subregion in the UNDO tool, rather than many to represent all biofilter areas.

Conversely, if there is public open space in the development that supports a living stream, and it is greater than 5% of the urban residential subregion, and has a different drainage typology, the user will need to split the area into two subregions: one to represent the public open space and the other to represent the urban residential land use.

Rule 4: Consider 'catchments' for structural treatments and treatment trains.

The UNDO tool can treat nutrients using a 'treatment train' approach. Examples are shown in Figure A-1.

Figure A-1: *Examples of treatment trains in UNDO*

The UNDO tool requires that at least one subregion completely drains to a treatment train, i.e. a single subregion can drain to a treatment train (Figure A-1a) or multiple subregions can be combined to drain to a treatment train (Figure A-1b). It is not possible for a proportion of a subregion to drain to a treatment train – if this is the case for a development area, the catchment of the treatment train must be split into an extra subregion in the UNDO tool.

It is important to note that this issue only occurs when a *treatment train* is entered; if a development has a series of disconnected treatments, these can be 'embedded' into a larger development in the UNDO tool (see Section 6-2 for more detail on how to embed treatments). Embedded treatments allow the user to enter the treated area (i.e. the catchment area for the structural treatment), with the condition that the treated area is equal to or smaller than the subregion area. Any number of disconnected embedded treatments can be added to a subarea. Figure A-2 shows an example of two embedded treatments in the UNDO tool (a biofilter and a swale), with the biofilter opened in 'editing mode'. Then, if disconnected treatments are used in a development, the UNDO tool does not require that catchments of each of the treatments are divided into extra subregions.

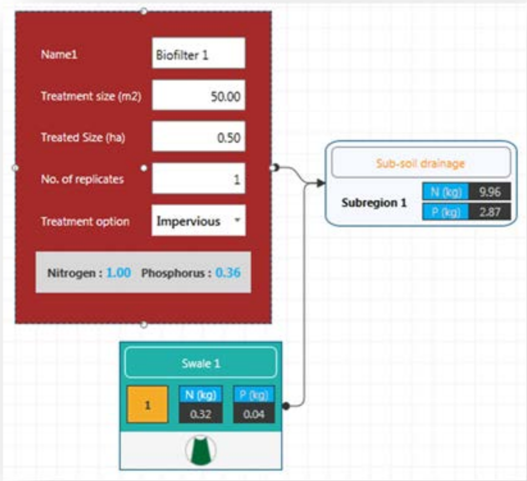


Figure A-2: *Example of embedded treatments in the UNDO tool. These treatments do not require that the entire subregion drains to the treatment, and the 'treated size' is entered by the user*

Rule 5: Revisit your UNDO tool project and build in complexity if required.

Undertaking an UNDO project is generally an iterative process. As a general rule, a first pass subregion design is entered initially into an UNDO tool project, and is based on soil and drainage properties of the development (See Appendix B). However, the development will generally be assessed against targets, and if the first pass of the development does not comply with targets, further nutrient treatment will be required. This may include implementing structural treatment trains, soil amendment, or possibly even a re-design of drainage. This will require the user to revisit the assumptions associated with the subregions and, in some cases, further divide the subregions based on the above rules.

Appendix B: A guide to subregion configuration based on drainage typology in the UNDO tool

Dividing a development into subregions, based on drainage type in the UNDO tool is relatively simple as long as the process is well understood. In most urban developments land-use categories will comprise a combination of:

- urban residential developments areas (which may include commercial or industrial areas)
- road reserves
- recreation and public open space
- possibly some larger lots zoned for rural living.

These land-use categories will rarely all have the same drainage type, and an UNDO project will probably require the development to be divided into subregions to represent each of the drainage types. For example, large lots associated with rural living areas do not generally pipe drainage water, and do not use subsoil drainage systems to control groundwater levels. Urban areas which use subsoil drains to control groundwater levels do not generally lay these subsoils drains beneath the public open space, and there are many combinations of road drainage network and urban drainage network – these range from full lot connections of the urban residential lot runoff to a piped road drainage network to the infiltration of all development water (negating the requirement for piping infrastructure completely). Many development areas use a combination of piped drainage network, a subsoil drainage network, and an open channel drainage network, so users of the UNDO tool may initially find it difficult to categorise the drainage type of their development. This section simplifies this process and provides a decision tree that will assist in creating subregions for their UNDO project based on the combination of drainage types for the development.

The decision tree (Figure B-1) leads the user to eight distinct drainage configurations. Each configuration is discussed in detail in the following sections, including an explanation of how to enter it into the UNDO tool, and where the types of configuration are generally used in south-west Western Australia. If a drainage configuration does not conform to any of these drainage types, the user is encouraged to consult the UNDO team for further advice (UNDO@water.wa.gov.au).

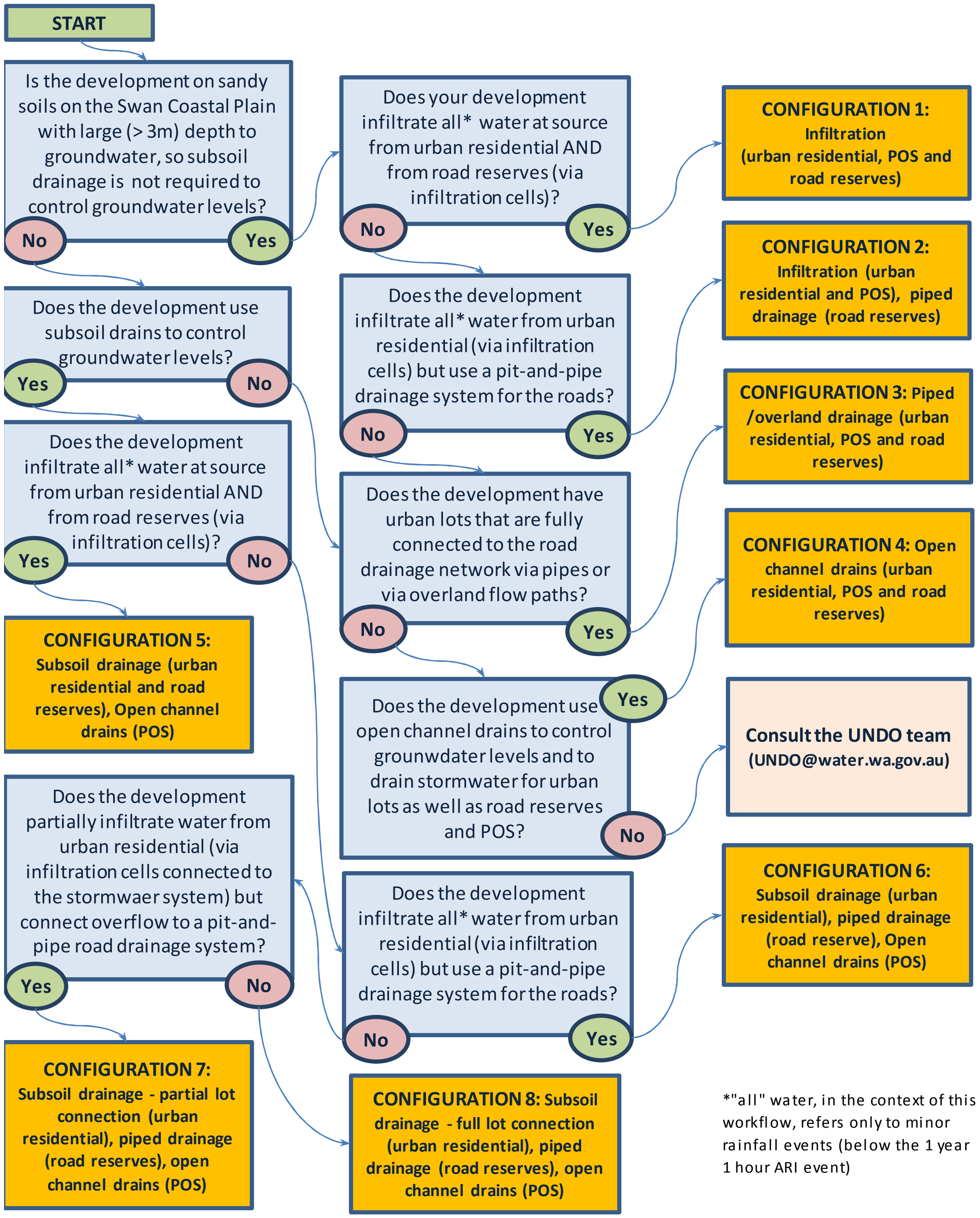


Figure B-1: *Decision tree for configuring subregions based on drainage type for the UNDO tool*

Configuration 1: Infiltration (road reserves, POS and urban residential)

Configuration 1: Infiltration systems are implemented in areas with sandy soils with sufficient depth to groundwater, where runoff from impervious surfaces from small rainfall events is infiltrated at source for road reserves, urban residential areas, and public open space. Runoff is infiltrated via infiltration cells, gardens and pervious paving for impervious roof and paving runoff for houses; roadside biofilters, tree-pits, pervious paving, swales and/or infiltration cells/trenches for road reserves; and infiltration basins, swales or biofilters for public open space. There is no connected stormwater system associated with a Configuration 1 drainage in UNDO. The conceptual model for *Configuration 1* drainage is shown in Figure B-2.

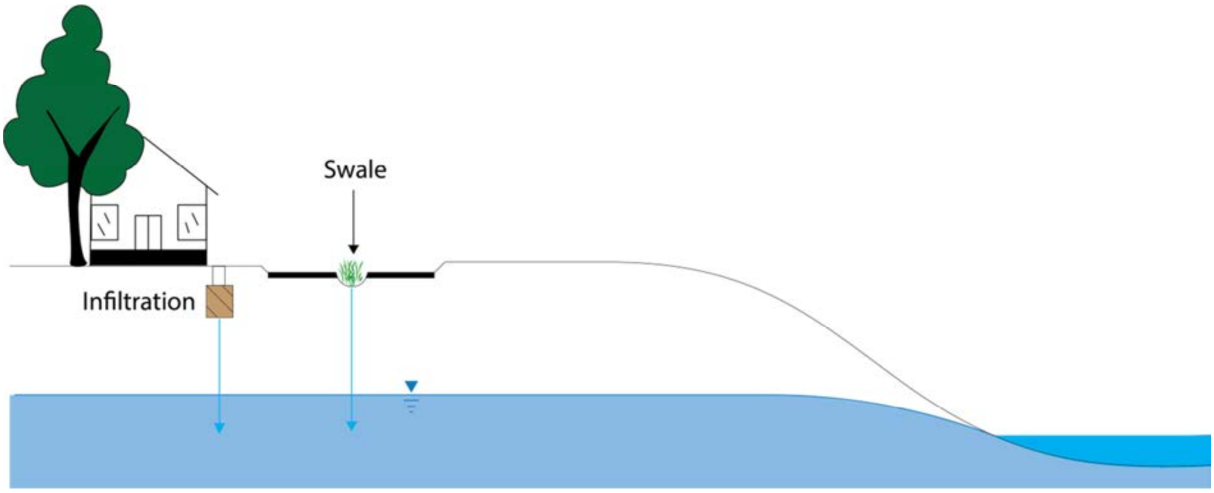


Figure B-2*: Conceptual model for the drainage Configuration 1: Infiltration (road reserve, POS and urban residential)*

Subregion configuration in the UNDO tool

It is possible for an entire development to be configured with only one subregion using a *Configuration 1* (provided the soil type and fill properties are relatively consistent throughout the area). This is because the residential, road reserve and public open space areas can all be represented by this drainage type. If the development area varies significantly in terms of soil type, depth to groundwater or groundwater gradient, multiple subregions will be required.

General application of drainage type

Configuration 1 drainage occurs along the coastal strip of the Swan Coastal Plain where there is sufficient depth to groundwater. It is also present on the Swan Coastal Plain, north of Perth, where the Gnangara Mound provides adequate separation from groundwater for this type of drainage.

Configuration 2: Infiltration (urban residential and POS) and piped drainage (road reserve)

Configuration 2 drainage consists of infiltration systems for the urban residential allotments and piped drainage for the road reserve allotments. This is a fairly typical scenario for existing and new urban developments in deep groundwater regions of the northern Swan Coastal Plain (common along the coastal strip where there are large sand dunes associated with the Tamala Limestone/Spearwood Sands). Runoff generated by small rainfall events for urban allotments infiltrates via infiltration systems (e.g. soakwells) for the impervious area or direct infiltration from impervious areas. Runoff from road reserves is routed through pits and pipes located at road verges, and usually discharged to biofilters or infiltration basins. A conceptual diagram for *Configuration 2* drainage is shown in Figure B-3.

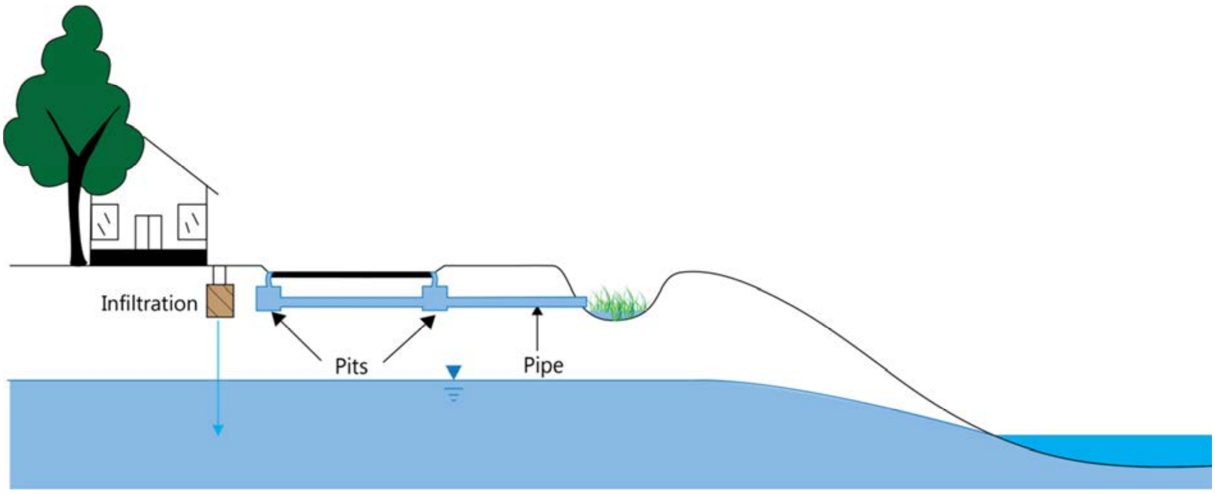


Figure B-3: *Conceptual model for the drainage Configuration 2: Infiltration (urban residential and POS) and Piped Drainage (road reserve)*

Subregion configuration in the UNDO tool

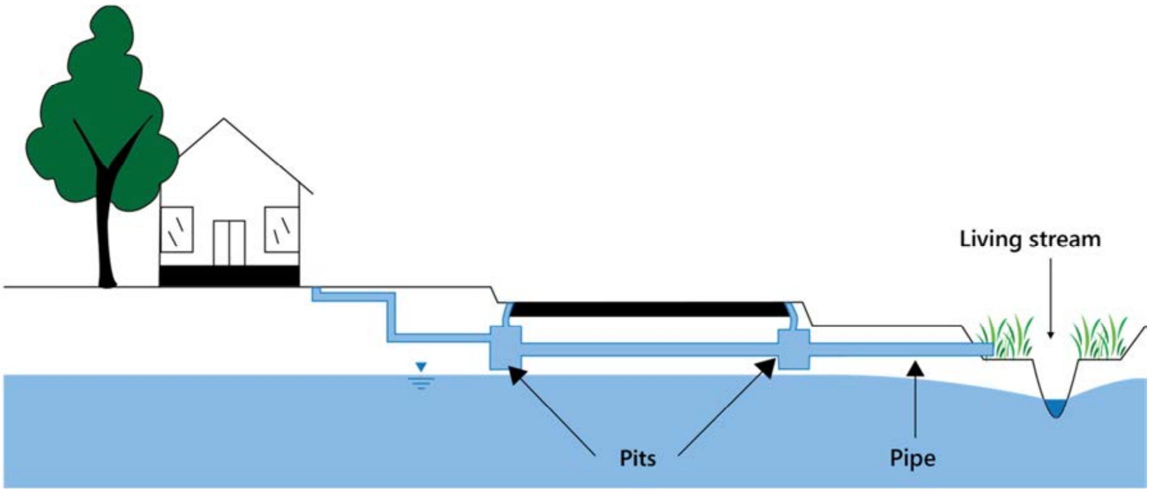
Configuration 2 requires that the UNDO tool's development splits the road reserve and the urban residential land-use categories into separate subregions. Generally, the public open space land category can be lumped with the residential land-use category, as these both use direct *infiltration* as the primary mechanism of drainage. The subregion that includes the road reserve land-use category will have *piped drainage* selected in the UNDO tool.

General application of drainage type

Configuration 2 drainage is common on the Swan Coastal Plain, particularly in new developments on Perth's coastal corridor. Pit-and-pipe drainage for road reserves is generally routed to infiltration basins or biofilters where water infiltrates to the deep groundwater (though in some older urban development areas, e.g. Scarborough, it is routed to ocean outfalls). *Configuration 2* drainage occurs along the coastal strip of the Swan Coastal Plain where there is sufficient depth to groundwater. It is also present on the Swan Coastal Plain, north of Perth, where the Gnangara Mound provides adequate separation from groundwater for this type of drainage.

Configuration 3: Piped/overland drainage (urban residential, POS and road reserve)

Configuration 3 drainage systems involve pit-and-pipe systems (or overland flow) as their primary mechanism for stormwater runoff. They are generally associated with heavy clay soils outside the sandy areas of the Swan Coastal Plain, but are also associated with road reserves on parts of the Swan Coastal Plain where pit-and-pipe systems are used to convey stormwater. Two conceptualisations of *Configuration 3* drainage configurations are shown in Figure B-4.



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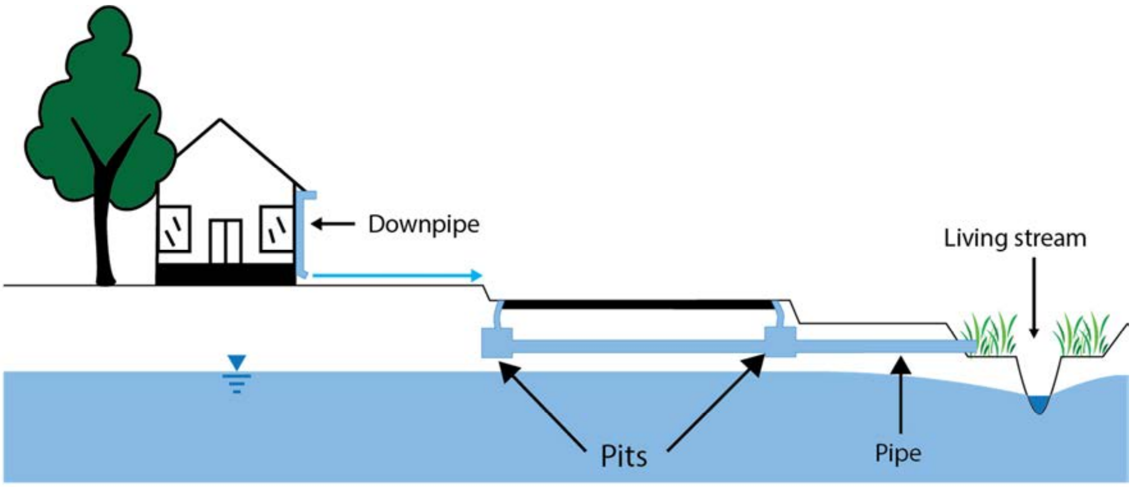

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***Figure B-4**: Two configurations for the conceptual model for Configuration 3: Piped drainage which includes A) piped drainage with lot connection, and B) overland flow for urban allotments that drain to a pit-and-pipe system for roads*

Subregion configuration in the UNDO tool

Residential lots (or commercial/industrial lots), public open space and road reserves can generally be lumped within the same subregion using a *Configuration 3* drainage (provided the soil type and fill properties are relatively consistent throughout the development area), as both land categories use a piped system for drainage. In some instances roof runoff and impervious runoff from urban lots will not be piped, but will drain to the road via overland flow (e.g. down the driveway) to the road where it enters a pit-and-pipe stormwater system. In this case the drainage typology for the urban allotments is assumed to be piped drainage for the purposes of the UNDO tool (Figure B-4b).

General application of drainage type

*Configuration 3*drainage configurations were very common on the Swan Coastal Plain in traditional urban developments (pre-2000), where a piped drainage network was combined with deep open channel drains that would lower groundwater levels, so subsoil drains were not needed. However, in the past decade water sensitive urban design principles have been adopted by most land developers, and this drainage typology is far less common on the Swan Coastal Plain. Outside the sandy coastal plain *Configuration 3* drainage is relatively common in urban developments with heavy soils; for example, on the Darling Scarp, the Perth Hills, or the Cape-to-Cape region around Margaret River.

Configuration 4: Open channel drains

Configuration 4 drainage is generally only used in the UNDO tool if the development is associated with rural living landuse (for roads, allotments and public open space). Open channel drains can also be associated with public open space in high water table developments.

The conceptual model for *Configuration 4* drainage is shown in Figure B5. On road reserves, open channel drainage is usually located on the left and right verges. Runoff from rural residential allotments will either infiltrate to the groundwater or flow overland to an open channel network. The channels generally drain both surface water and groundwater. If *Configuration 4* drainage is selected in UNDO, by definition the development area cannot have any pit-and-pipe network, and subsoil drainage systems are not used to control groundwater levels.

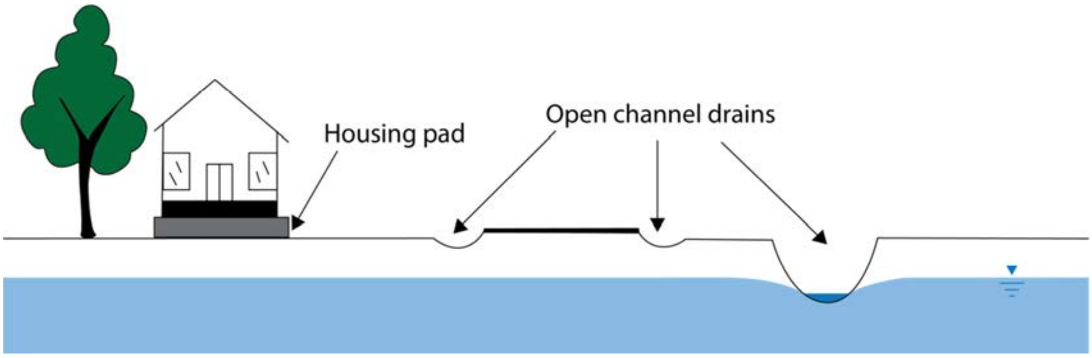

***Figure B-5**: Conceptual model for the drainage Type 1: Open channel drains*

Subregion configuration in the UNDO tool

Configuration 4 drainage is generally associated with the rural living land-use category. In the UNDO tool, this land-use category is one of the only examples where it is possible for an entire development to be represented by a single subregion (provided the soil type is relatively consistent throughout the development area). This is because the residential, road reserve and public open space areas can all be represented by *open channel drainage*. In instances where part of a development comprises rural living allotments and another part has higher density urban allotments, the development will need to be split into subregions.

General application of drainage type

Configuration 4 drainage (open channel drains in rural living areas) is generally used where it is not feasible to develop a piped stormwater network and where there is sufficient space for open channel drainage systems negating the need for piped or subsoil systems (other than crossings). *Configuration 4* drainage can be used on the sandy sections of the Swan Coastal Plain or on heavier soils. In the sandy sections of the Swan Coastal Plain, inundation is generally managed by agricultural drainage and groundwater is generally close to ground level with fill used to provide separation between house foundations and groundwater. In heavier soils with deeper groundwater (for example, associated with developments on the Darling Scarp), there usually much more relief, and the channels are generally more natural waterways.

Configuration 5: Subsoil drainage (urban residential and road reserve)

Configuration 5 drainage systems use subsoil drains (slotted piping) to control groundwater levels and as such provide a drainage outlet for water infiltrating from urban lots and road reserves. This type of drainage is associated with high groundwater areas on the Swan Coastal Plain. *Configuration 5* drainage systems do not use pit-and-pipe systems for stormwater conveyance, and all runoff from small rainfall events infiltrates 'at-source'. Runoff from roads infiltrates at-source via roadside swales, biofilters or infiltration cells/trenches. A conceptual model is shown in Figure B-6.

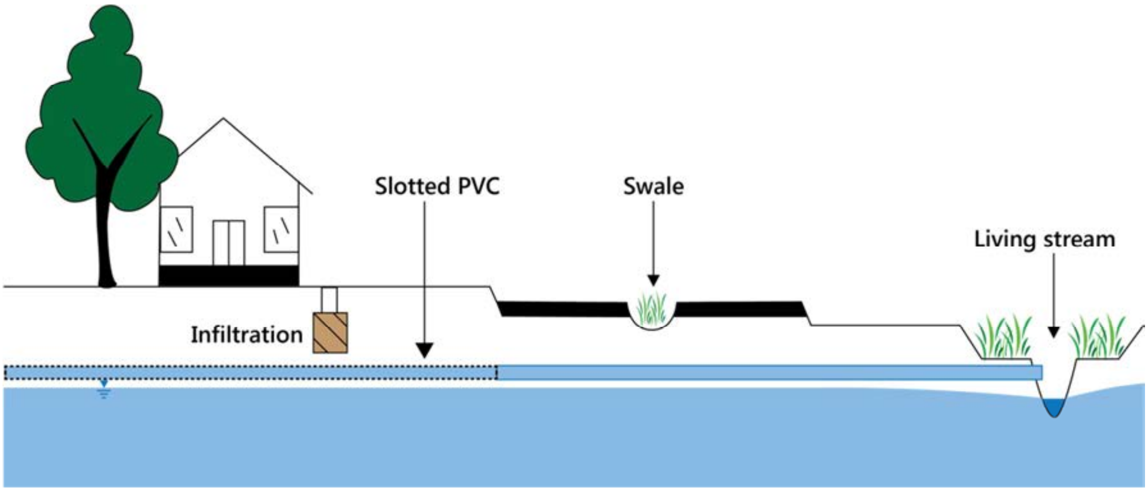

Figure B-6*: Conceptual model for the drainage Configuration 5: Subsoil drainage (road reserve and urban residential)*

Subregion configuration in the UNDO tool

In the UNDO tool, the urban residential and road reserve land categories can generally be lumped into the same subregion with *Configuration 5* drainage (provided the soil type and fill properties are relatively consistent throughout the development area). However, public open space (particularly public open space used for drainage management) rarely uses subsoil drains to control the groundwater level, and in these instances the public open space will require a separate subregion and drainage type (generally o*pen channel drains* or *infiltration*, depending on whether a living stream or channel drain is present).

General application of drainage type

Configuration 5 drainage is used in developments on the Swan Coastal Plain with shallow groundwater. This drainage type is associated with new developments in the southern Swan Coastal Plain, between Perth and Busselton, inland from the coastal dunes and west of the Darling Scarp. This drainage is generally associated with Bassendean or Guildford soils (where sand fill is used to create a separation between lot levels and the groundwater table). It is recommended that water in subsoil drains is treated before it is discharged to living streams or to the catchment outlet.

Configuration 6: Subsoil drainage (urban residential) and piped drainage (road reserve)

Configuration 6 drainage systems use subsoil drains (slotted piping) to control groundwater levels beneath urban allotments, and pit-and-pipe stormwater systems for road runoff. This drainage type is associated with sandy soils and high groundwater levels, usually on the southern Swan Coastal Plain inland from the coastal strip. A conceptual model is shown in Figure B-7.

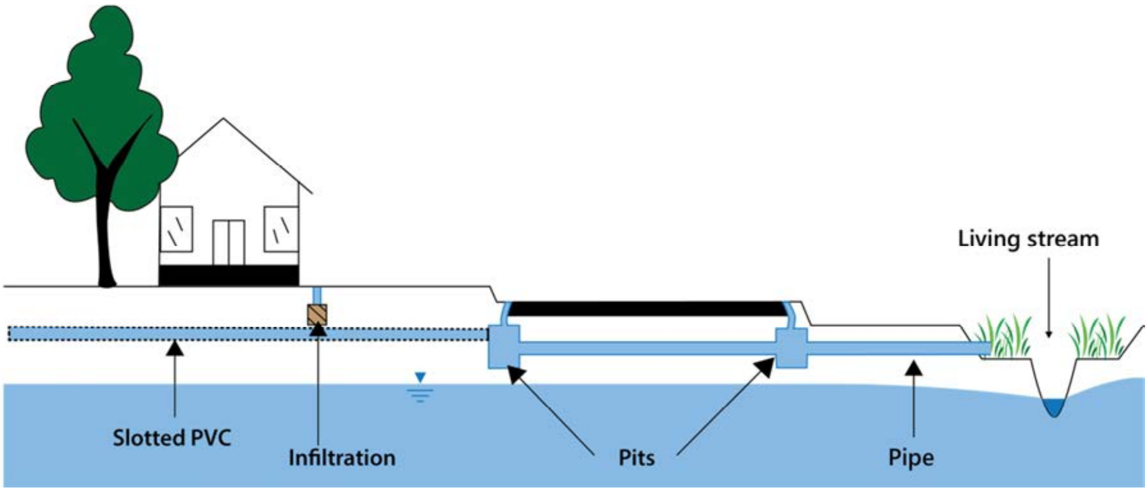

Figure B-7: *Conceptual model for the drainage Configuration 6: Subsoil drainage (urban residential) and piped drainage (road reserve)*

Subregion configuration in the UNDO tool

Configuration 6 drainage requires that the UNDO project puts the road reserve and the urban residential land-use categories into separate subregions. In addition, the public open space land category will usually require splitting to a separate subregion, as public open space rarely uses subsoil drains to control the groundwater level. Urban residential land use is categorised with *subsoil drainage*, the road reserve land category with *piped drainage*, and the public open space with *infiltration* or *open channel drains*, depending on whether a living stream or drainage channel is present.

General application of drainage type

Configuration 6 drainage is very common in new development areas on the Swan Coastal Plain, where groundwater is shallow and subsoil drains are required to control the groundwater level. These drainage systems are associated with new developments in the southern Swan Coastal Plain, between Perth and Busselton inland of the coastal dunes but west of the Darling Scarp. *Configuration 6* drainage is generally associated with Bassendean or Guildford soils (where sand fill is used to create a separation between lot levels and the groundwater table). The subsoil system used to control groundwater levels under urban lots and road reserves usually discharges to the pit-and-pipe network associated with roads, then generally routed to biofilters, swales or living streams.

Configuration 7: Subsoil drainage – partial lot connection (urban residential) and piped drainage (road reserve)

Configuration 7 drainage systems involve a hybrid piped/infiltration system for impervious runoff from urban developments connected to a pit-and-pipe roadside stormwater system. These systems are also referred to as ‘partial lot connection’, meaning that the impervious runoff from urban developments is routed directly to small infiltration cells/detention tanks which can overflow to the roadside stormwater system via overflow pipes. These systems also use subsoil drains (slotted piping) to control groundwater levels underneath urban lots. The conceptual model is shown in Figure B-8.

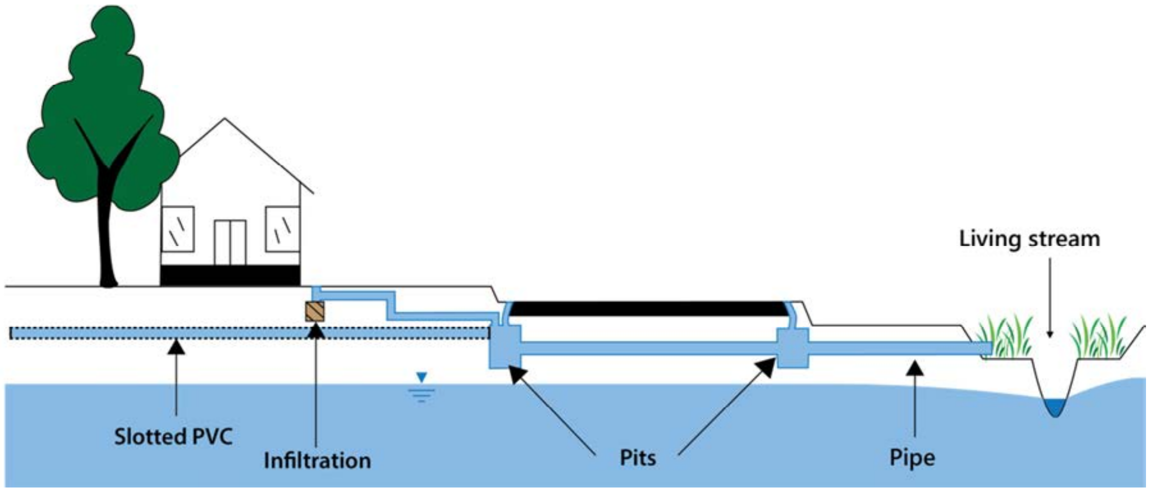

***Figure B-8**: Conceptual model for the drainage Configuration 7: Subsoil drainage – partial lot connection (urban residential) and piped drainage (road reserve)*

Subregion configuration in the UNDO tool

Configuration 7 drainage requires that the UNDO project divides the road reserve and the urban residential (or commercial/industrial) land-use categories into separate subregions. In addition, the public open space land category will generally require a different subregion, as public open space rarely uses subsoil drains to control the groundwater level. The urban residential land category will be categorised with *subsoil drainage – partial lot connection*, the road reserve land category with *piped drainage*, and the public open space with *infiltration* or *open channel drains*, depending on whether a living stream or drainage channel is present.

General application of drainage type

Configuration 7 drainage systems are occasionally used in new development areas on the Swan Coastal Plain where groundwater is shallow and subsoil drains are required to control the groundwater level. This is most prevalent in recent developments in the southern Swan Coastal Plain, between Perth and Busselton, inland of the coastal dunes but west of the Darling Scarp. The subsoil system used to control groundwater levels will drain to the pit-and-pipe network associated with roads, and the infiltration systems associated with urban allotments will overflow to a piped system that will drain to the roadside stormwater system. The pit-and-pipe drainage network is generally routed to biofilters, swales or living streams.

Configuration 8: Subsoil drainage – full lot connection (urban residential) and piped drainage (road reserve)

Configuration 8 drainage systems involve a piped system for impervious runoff from urban lots which connect to a pit-and-pipe roadside stormwater system. These systems are also referred to as 'full lot connection', meaning that the impervious runoff from urban developments is routed directly to the roadside stormwater system via overflow pipes. These systems also use subsoil drains (slotted piping) to control groundwater levels. The conceptual model is shown in Figure B-9.

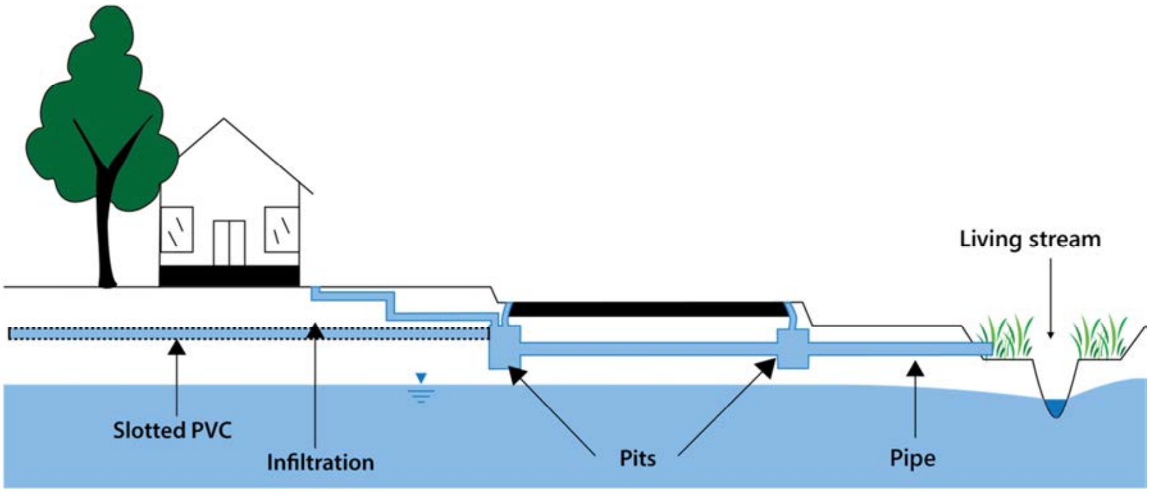

Figure B-9*: Conceptual model for the drainage Configuration 8: Subsoil drainage – full lot connection (urban residential) and piped drainage (road reserve)*

Subregion configuration in the UNDO tool

Configuration 8 drainage configuration requires that the UNDO project divides the road reserve and the urban residential land-use categories into separate subregions. In addition, the public open space land category will generally require a different subregion, as public open space rarely uses subsoil drains to control the groundwater level. The urban residential land category will be categorised with *subsoil drainage – full lot connection*, the road reserve land category with *piped drainage*, and the public open space with *infiltration* or *open channel drains*, depending on whether a living stream or drainage channel is present.

Configuration 8 drainage systems are relatively common on the Swan Coastal Plain in high groundwater areas, and are generally associated with small lots (generally < 300 m^2), where the local government deems that there is insufficient space to install appropriate infiltration cells or the site is geotechnically constrained and infiltration cells are unsuitable. *Configuration 8* drainage is associated with new developments on the southern Swan Coastal Plain between Perth and Busselton, inland of the coastal dunes but west of the Darling Scarp. The Department of Water recommends that this type of drainage is only used for dense lot configurations in highly constrained areas, and sufficient justification to this effect will be required if such a design is proposed. If stormwater cannot be managed on lot, then management should be undertaken as near to the source as possible, for example in the road verge or median.

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